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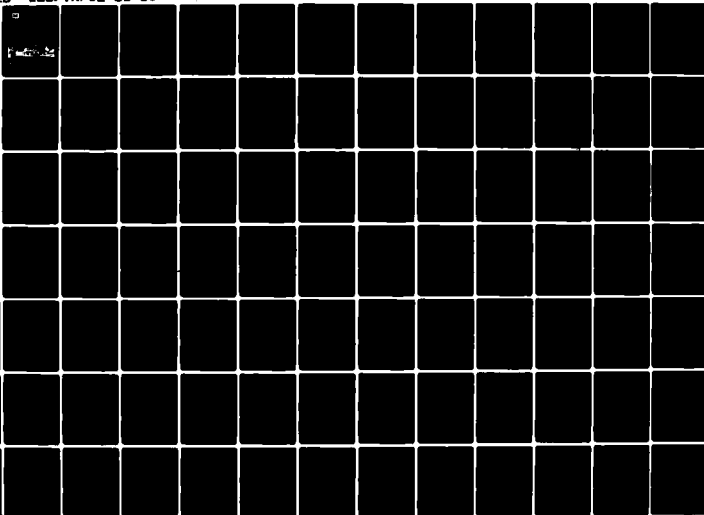
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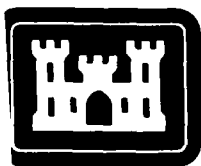
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TUNNEL COST-ESTIMATING METHODS

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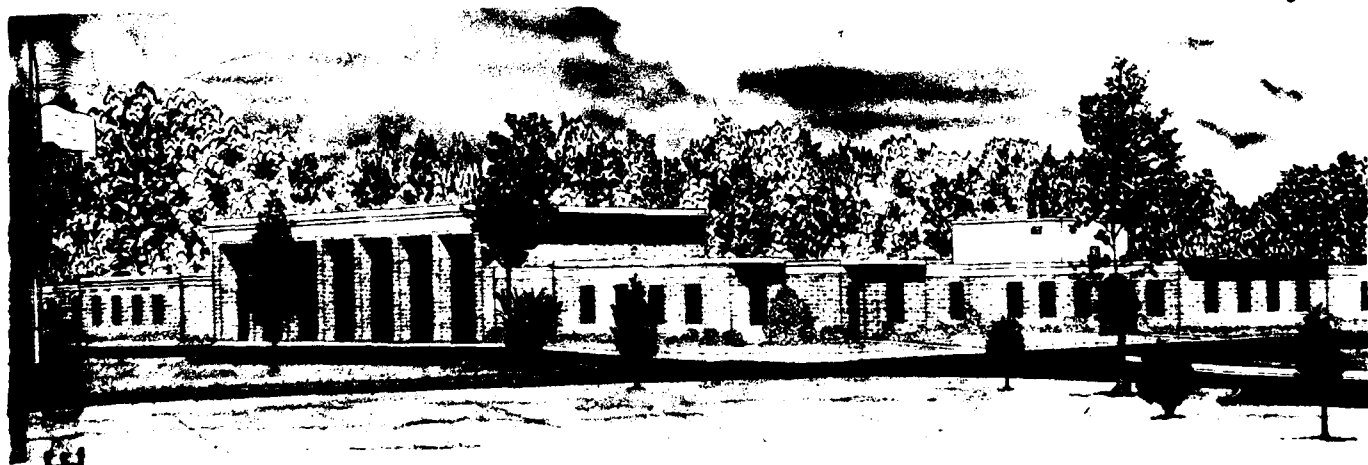
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October 1981
Final Report

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20. \ ABSTRACT (Continued)

This report describes an investigation of various tunnel construction cost-estimating techniques. Manual and computer methods are described and compared, important elements of tunnel construction are discussed, and an evaluation is made of the most promising computer cost model, using case histories of three completed tunnels for which good documentation was available.

The cost-estimating methods described herein can be used to develop more comprehensive and accurate estimates for tunneling, than the method presented in EM 1110-2-502, Methodology for Areawide Planning Studies, MAPS, Part 2, Chapter 14, dated 28 November 1980. Plans are being made to improve the MAPS tunnel-cost functions to reflect the improvements identified during this study.

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PREFACE

The study reported herein was performed under the RDT&E Program, Project 4A762719AT40, Work Unit EO/005 entitled "Improved Tunnel and Rock Cavity Support Systems," sponsored by the Office, Chief of Engineers (OCE), U. S. Army. Mr. D. S. Reynolds was the OCE Technical Monitor.

The investigation was conducted by the U. S. Army Engineer Waterways Experiment Station (WES) during the period FY 77-FY 80. The study was conducted under the direct supervision of Mr. J. S. Huie, Chief, Rock Mechanics Applications Group (RMAG), Geotechnical Laboratory (GL), and under the general supervision of Dr. D. C. Banks, Chief, Engineering Geology and Rock Mechanics Division; Dr. W. F. Marcuson III, Chief, GL; and Dr. P. F. Hadala, Assistant Chief, GL. Mr. R. D. Bennett, RMAG, prepared the report.

Commanders and Directors of the WES during the investigation and preparation of this report were COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
acres	4046.8	square metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
gallons per minute	0.003785	cubic metres per minute
inches	25.4	millimetres
miles (U. S. statute)	1.61	kilometres
pounds (force) per square foot	4.882	kilograms per square metre
pounds (force) per square inch	703.1	kilograms per square metre
pounds (mass) per cubic foot	16.02	kilograms per cubic metre

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

TUNNEL COST-ESTIMATING METHODS

PART I: INTRODUCTION

Background

1. Tunnel construction in the United States has been characterized as a high-risk, high-cost business. Cost overruns and delays have been especially damaging to public support for rapid transit tunnel projects and, to a lesser extent, to water tunnels. This support is critical since most tunnels are built and maintained with taxpayers' dollars. Consequently, decision makers have been forced to consider the following difficult questions:

- a. What factors cause these overruns, what is the relative impact of each factor, and what can be done to improve the assessment of these factors?
- b. What is needed to make tunnels more competitive with aboveground alternatives?
- c. The big question: Are these projects necessary and in the best interests of the taxpayer or are there better alternatives?

2. Much research has been sponsored by public agencies to find answers to these questions. Institutional factors have been studied (Mayo et al. 1968 and 1976, and National Research Council 1974). Such factors include the business climate, the reputation of the owner, the relative demand for tunnel construction and competing construction, which influences bid prices, risk, and profitability, and the general owner-engineer-contractor relationship. The barriers to technological innovation and to increased competition through the entry of new firms into the market have been studied, and recommendations have been made for improving the current situation. This report deals with one part of the overall problem; i.e., given the natural variability of underground conditions, the productivity of various combinations of men and equipment capable of constructing a tunnel, and the uncertainty of the economic climate, how reliable can the estimate of the cost of this planned

construction be? A companion question to which answers were sought was, what is the relative cost impact of each of the identifiable items of uncertainty?

Purpose

3. The purpose of this study was to develop or adapt reliable methods for estimating tunnel construction costs that could be used by planners and designers who are not necessarily tunnel experts or estimators.

Scope

4. This report presents the results of a study of tunnel cost-estimating methods. Important elements of tunnel construction are summarized and manual methods and computer models for estimating tunnel costs are described and compared in Part II. The computer model (COSTUN) was selected for in-depth study using case histories of completed tunnels. The three types of estimates prepared for each of the three selected case histories are as follows:

- a. Estimates were prepared using all information known to be available to bidders. These estimates were compared with the engineer's estimate and contractor's bids.
- b. Estimates were prepared using all information available at completion of the tunnel. These estimates were compared with the as-built cost and the preconstruction estimates and bids.
- c. Parameter studies were made using all information known to bidders. Several estimates were prepared to assess the cost consequences of assigning different values to one factor while holding all other factors constant.

5. The results of the analysis of COSTUN using tunnel case histories are discussed in Part III, and the summary and conclusions are presented in Part IV. A complete user's guide for the COSTUN computer program is contained in Appendix A.

PART II: DESCRIPTION OF ESTIMATING METHODS

6. In this section, a general discussion of tunneling and tunnel cost estimating is presented, and manual methods, including the use of cost curves, are discussed. Four computer models for estimating costs are described and compared.

Elements of Tunnel Construction

7. Before planning and estimating the cost of a tunnel, it is necessary to understand the different equipment and work methods that can be used to accomplish the job. Tunnel construction equipment may be divided into three main groups: (a) excavation equipment such as drills, jumbos, tunnel-boring machines, roadheaders, and mucking machines; (b) tunnel haulage equipment such as front-end loaders, trains, and conveyors; and (c) service equipment and facilities such as ventilation and air conditioning, generators, hoists, and lights. Although the selection of service equipment and haulage equipment is not much affected by the selection of the heading excavation method, the selection of excavation equipment is definitely dependent on this method. Parker (1970) and Mayo et al. (1968, 1976) provide thorough treatments of tunneling from different perspectives.

8. The actual construction of the tunnel consists of six main operations:

- a. Excavation.
- b. Muck disposal.
- c. Primary support installation.
- d. Pumping, grouting, or other ground control measures.
- e. Ventilation and air conditioning.
- f. Permanent lining installation.

The methods and timing for each of these operations may be varied to fit project requirements, site characteristics, and to some extent, designer or contractor preference. Excavation methods and equipment commonly

used are described in the following paragraphs. A more detailed discussion of various methods used in construction of tunnels and shafts is contained in EM 1110-2-2901 (Dept. of the Army, Office, Chief of Engineers (OCE), 1978).

Conventional tunnel driving (drill and blast method)

9. Three major operations characterize this method of advancing a rock tunnel face. First, a burn cut is drilled at the center to allow room for rock expansion. Additional rings of holes are then drilled into the face on a predetermined pattern, using air or hydraulically operated drills mounted on a movable platform or jumbo. The holes are then loaded with dynamite or ANFO (a mixture of ammonium nitrate and fuel oil) and exploders that are connected to an electrical firing circuit. Men and equipment are then moved back a safe distance and the round is fired. After ventilation of powder fumes, the mucker is moved in and loads the broken rock into muck cars. Then the muck is transported to the surface and disposed of, the mucker is moved back, and the drill jumbo again advances to the tunnel heading to start another round. Depending on rock conditions, grouting to stop groundwater inflow, support placement, and exploratory drilling ahead of the face may be necessary before another round is drilled for explosives.

10. Major decisions that must be made in the planning stages of a conventionally driven tunnel include whether air, electric, or diesel power will be used and whether equipment will be rubber-tired or travel on rails. The basis for selection of power options and equipment mobility are covered in detail by Parker (1970) and are only summarized in this report.

11. Several variations may be used in conventional tunnel driving to accommodate special conditions. In good rock, full-face excavation is the favored method, but in poor rock or a mixed face, or in very large tunnels or caverns, heading and bench or multiple drift methods may be used. When heading and bench excavation is used, the top is normally driven portal to portal before excavating the bench. This practice allows the use of the drill jumbo in both operations. Prior to

about 1940, before jumbos became popular, the bench was usually excavated just behind the heading, with only a short 10 to 15-ft* working platform left.

12. Multiple-drift excavation is used when the crown must be continuously supported. Drifts may be driven at opposite springlines with rockbolts and shotcrete used for support. The rockbolts may extend transversely across the crown of the main tunnel so that it may then be safely mined. There are variations in the placement of drifts to meet special cases.

13. In a mixed-face excavation, part of the tunnel face consists of crushed rock or soft ground and the remainder is more competent rock. Forepoling or spiling is used to support the roof between the nearest steel set and the face. Sharpened wood spiles or steel rods are driven into the roof at a shallow angle from behind the nearest support and extended some distance beyond the face.

14. Blasting patterns vary for different conditions and because of contractor preference. The many options and factors that should be considered to develop an efficient blasting pattern are discussed in detail in EM 1110-2-2901 (Dept. of the Army, OCE, 1978). Blast holes are normally drilled either 8 or 12 ft deep. Two popular patterns are the angled cut and the burn cut. A combination of the two is also used. With the angled pattern, four cut holes are angled from the face to intersect at the axis and are heavily charged. Next, a ring of relief or easer holes is drilled, followed by one or more rings of enlarger holes, depending on the tunnel diameter. The outermost holes are the trim holes. Trim holes in the invert are called lifters. Successive rings are detonated after predetermined delays, starting with the cut holes at the axis. The trim holes are fired last. The lifters in the invert may be fired before or after the trim holes around the crown and spring lines, depending on the desired shape and size of the muck pile. The burn cut pattern uses one or more large diameter uncharged holes at the

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

axis to allow room for rock expansion when the outer rings are detonated. Again blasting proceeds from the easier holes to the trim holes, usually with predetermined delays between detonations of successive rings.

15. Jumbos for drilling the blast holes may run on the same track as rail muck cars or may straddle the muck car tracks on wide gauge rails, or in large tunnels, the jumbo may be rubber-tired. In small tunnels, with insufficient head space for a jumbo, lightweight air-leg drills may be used.

16. Mucking in small tunnels may be accomplished using a rail-mounted, air-operated, rocker-type shovel that loads the muck cars. In larger tunnels, an electric-powered mucker may scoop the muck onto a short conveyor section that dumps into the muck cars. The muck cars are pulled by electric or diesel-powered locomotives; if rail cars are used in steep-sloped tunnels, they may be winched. In very large tunnels, rubber-tired equipment is usually chosen for muck loading and hauling.

Tunnels driven with a shield

17. Shield-driven tunnels get their name from a steel plate shaped to fit the outside dimensions of the tunnel. The shield is used to prevent loose material from flowing or running into the excavation and must be jacked against the face. The miners excavate the face work under the front section of the shield, while supports are erected inside the rear section of the shield. As the face is excavated, the shield is jacked forward and slides past the previously erected supports. Tunnel support is transferred from the shield to the supports that may be cast iron, steel, or precast concrete segments. The annular space left by the thick shield plate is filled with pea gravel and grouted soon after jacking the shield forward. The use of a shield is dictated by poor ground that cannot be safely mined otherwise. In running ground, breastboarding at the face is required.

Tunnels driven under air pressure

18. Tunnels driven through soft ground below the water table or through crushed water-bearing rock zones require the use of compressed air in conjunction with the shield and partial or full breast boards at

the face. The air pressure is maintained by use of an air lock in the rear of the shield or at the portal. Sufficient pressure to balance the hydrostatic head is maintained forward of the air lock. Work hours are restricted proportional to the air pressure used, and a medical lock with a full-time attendant must be provided. Costs are proportionately higher for compressed air tunnels. The West Germans have recently introduced a successful slurry shield, the Hydrashield, which balances the hydrostatic pressure at the face with a bentonite slurry under pressure and thus eliminates the need for compressed air work.

19. Tunnels driven by boring machine (mole). This method of excavation replaces the cycle of drill, blast, and muck with (nearly) continuous simultaneous excavation and mucking. In soft, competent rock conditions, moles make faster progress than conventional driving methods. The mole or tunnel boring machine has a round rotating or oscillating cutterhead that may be fitted with any of several types of bits, teeth, or discs, depending on the type of material encountered. The material removed by the cutter is scooped from the invert by a muck bucket that rotates with the cutterhead. The muck is dumped on a conveyor belt and carried away from the face, either to the shaft or portal or to muck cars behind the mole. Moles may be used with shields in incompetent materials or soft ground, but better progress is made in soft, consistent rock where a shield is not necessary. Excavation in very hard rock wears down the bit very quickly; stratified rock or mixed face results in uneven thrust and excessive bearing wear and can cause large rocks to jam between the tunnel wall and rotating cutterhead.

Tunnel Estimating

20. Tunnel estimating is the art of conceiving a job on paper and properly evaluating the cost of planned construction. The assumptions and decisions that form the basis for cost computations are made by comparing cost records of similar completed projects, assuming a synthetic organization of men and equipment and rates of material usage and progress, or a combination of the two. A cost estimate can be prepared

manually or with the aid of a computer, but the basic decisions that must be made are identical and often both methods are used as a check. To develop a synthetic model, the method of excavation must be chosen, types and amount of equipment selected, progress rates assumed, crew sizes and makeup decided, and man-days required to accomplish the job estimated. The actual estimate quantifies the cost of the various inputs, including equipment, labor, materials, supplies, supervision, and escalation. Normal contingencies, risk, interest, and profits are not included in the estimate but compose the markup added to the estimate to arrive at a bid price. Engineering design and inspection are usually absorbed by the owner and are not included in the estimate. On a manual estimate, an estimator sets down all computations and afterwards presents the quantities and costs on a spread sheet that must conform to the owner's format in the request for bids. For a computer estimate, production rates, crew sizes, wage rates, and work hours are among the necessary inputs to produce a tabulated cost estimate. There are disadvantages and advantages of each method. Probably no contractor has ever submitted a tunnel bid prepared solely by a computer; a manual estimate gives them more confidence in the assumptions and calculations used and serves as a check on the black box. On the other hand, the computer method allows an owner's representative to evaluate many alternatives to optimize route selection, support design, depth of cover, shape, excavation method, and other factors to arrive at the most economically feasible option in the time available. A hand-calculated estimate may then be prepared on the most promising alternatives as a check. Obviously, then the selection of the method depends on the intended use of the estimate.

21. The following paragraphs present a discussion of the procedures for preparing a detailed manual estimate, a preliminary estimate using unit cost data, and the use of cost curves.

Manual estimates

22. The steps involved in preparing a detailed manual estimate follow:

- a. Obtain and study plans and specifications.
- b. Inspect site.
- c. Review aerial photographs, geological reports, and boring logs.
- d. Tabulate quantity takeoffs.
- e. Obtain quotes from suppliers, insurance and bonding companies, and subcontractors.
- f. Determine wage rates.
- g. Prepare construction schedule.
- h. Select excavation method.
- i. Select equipment.
- j. Estimate cost of equipment rental or purchase.
- k. Determine crew size and makeup.
- l. Estimate progress rates.
- m. Estimate cost of aboveground development.
- n. Estimate cost of tunnel excavation supplies.
- o. Estimate cost of tunnel excavation labor.
- p. Estimate cost of support and lining supplies.
- q. Estimate cost of plant.
- r. Estimate cost of concrete-lining labor.
- s. Estimate direct cost of other bid items.
- t. Tabulate all direct costs.
- u. Estimate indirect costs.
- v. Estimate camp costs.
- w. Estimate escalation.
- x. Tabulate total estimated costs of project in format required by request for bid.

All the steps above are interrelated and must be checked back and forth. For example, the initial construction schedule may be altered several times, but the contract end date must be adhered to. Thus men and equipment may have to be added to accomplish some tasks more quickly. The plans and specifications will be referred to countless times, i.e., after the site visit to check the impact of new information gained about access, labor wage rates and availability and their impacts on particular excavation methods, blasting restrictions, availability and cost of

power and water, etc. The review of geological information may indicate that a favored method of excavation or groundwater control will not work, necessitating changes. It is a good idea to prepare a checklist, and as each step is completed, compare them to determine if there are conflicts that must be resolved before moving to the next step. Quantity takeoffs must be calculated for each supply item or task and tabulated for convenient identification and cost of every aspect of the job. Requests for quotations from equipment and materials suppliers are made at the earliest possible date, even before the excavation method is chosen, to nail down these costs. These quotes serve as the basis for evaluating alternative methods and equipment.

23. Wage rates and availability are usually determined during the site visit, but they may change before the contract is awarded and so must be watched carefully. Selection of the excavation method sets the stage for many of the subsequent decisions and must be carefully weighed against required equipment purchases versus equipment currently owned, required crew makeup, manufacturer's lead time, and a host of other factors. Currently owned machines are always favored if they are suitable for the tasks. Selection of muck haulage and service equipment is not much affected by the excavation method. Tunnel length, size, shape, distance to disposal, and time allowed for completion do have a major impact on types and numbers of equipment used. Similarly, crew size and makeup are dependent on methods and equipment used. The advance rates that can be achieved are tied to all these factors; the slowest unit of production is the controlling one. For example, a tunnel boring machine may be capable of excavating 50 ft per shift, but if it is mated with a muck removal system that is slower or breaks down often, the mole will never develop that rate. In drill and blast tunnels, the length of rounds must be balanced against the capacity and cycle time of the muck removal system. Juggling men and equipment, length of rounds, etc., may be required to achieve the best possible efficiency. In some cases, more men and equipment might speed up mucking, but limited work space in small tunnels might preclude this effort. In such a case, multiple headings or alternating headings may be advantageous. To

achieve a synchronized efficient advance rate with the least possible idle time is one of the most difficult, yet necessary, tasks in tunnel construction. It cannot be done with any finality on paper but requires continuous monitoring and the ability to adapt quickly to changing conditions.

24. When the best estimate of progress rates has been arrived at, the next step is to tally the direct and indirect costs of each pay item. Direct costs may be arranged in the following categories after the equipment, crew makeup, advance rates, and quantities have been set:

- a. Access and supply logistics (mobilization).
- b. Tunnel excavation.
 - (1) Labor.
 - (2) Materials.
 - (3) Equipment.
- c. Primary support.
 - (1) Labor.
 - (2) Materials.
 - (3) Equipment.
- d. Lining.
 - (1) Labor.
 - (2) Materials.
 - (3) Equipment.
- e. Demobilization and salvage.

25. Indirect costs must be developed next. Checklists are time-saving aids for this task and can be used for insurance, plant, field overhead, and office supervision. The effects of inflation and the data used by the contractor to develop a cash-flow forecast must be checked. In some instances, the figures may be juggled to produce a more favorable cash flow during the early stages of the contract. This practice is known as unbalancing the bid. An owner's representative is less concerned about cash flow but must consider the yearly budget requests and needs of the owner if the tunnel is publicly owned. (Most tunnels are owned by state and federal agencies). The estimated costs, when totaled, will be the basis of the build-no build decision by the owner and the bid-no bid decision by the contractor. In addition, the contractor must consider other market conditions, including interest costs, minimum

attractive rate of return, business-mix objectives, key personnel, etc., and balance this job against other tunnel jobs or other heavy construction, each with its own set of potential rewards and penalties.

26. The steps required to manually estimate the cost of tunnel construction have been outlined. According to personnel in large tunnel construction firms, the average time required to prepare a detailed tunnel estimate is three weeks and ranges from two weeks to two months.

Unit cost method

27. The unit cost method of estimating tunnel costs is a well-accepted simple technique for making preliminary or planning estimates. It relies on historical records of similar jobs. Basically, the estimator prepares quantity takeoffs for the tunnel and determines the unit cost of each item by comparison with other similar tunnels. These costs may or may not be adjusted for inflation, regional differences, etc. The sum of the unit cost times the quantities of each item yields the tunnel cost. Obviously, this simplified method may not reflect the actual cost for several reasons: (a) differences in locations, construction methods, special site conditions, etc., are not accounted for and may not be recognized; (b) if unit cost data are developed from the three lowest bids, as is often the case, the common practice of unbalancing bids will distort the unit costs. However, the total cost may not be affected much because an unbalanced bid is just a redistribution of the total cost to improve cash flow in the early stages of a project; (c) unless adjustments are made for inflation, large errors may result; (d) bidding climate influences are not accounted for, such as the number of prospective bidders and number of competing jobs. However, only the profit margin would be affected, and since profit margin ranges from about 3 to 20 percent, this omission would not negate the unit cost method's usefulness for preliminary estimates or comparison of alternatives.

Tunnel cost curves

28. One of the earliest reported developments to improve the reliability and reduce the time required for preliminary tunnel estimates was made by the California Department of Water Resources (1959). Their

need for reliable preliminary estimates to aid in route selection led to the formulation of a family of "cost curves." Case histories were analyzed to determine the cost impact of all factors involved in tunneling. They considered four major construction items affecting cost: excavation, support, dewatering, and lining. For each item, a family of cost curves was developed. Each curve represented a specified geological classification. The curves were plotted as item cost per foot of tunnel versus tunnel diameter. This work was done before moles and other tunneling advances were widely used. Consequently, the curves were representative of costs for conventionally (drill and blast) excavated tunnels, using standard steel-set support design (Proctor and White 1946). Soft ground, cut and cover, and mole excavation were not considered. Only circular-shaped tunnels were analyzed. The cost-per-foot figures were lump sum, not subdivided for labor, equipment, and materials, or profit, contingency, and overhead. Prior to the years of rapid inflation, these curves served their purpose quite well. The estimator simply entered the family of curves with a known tunnel diameter and estimated the length of each representative geological classification, then found the appropriate cost per foot for his tunnel. The cost per foot multiplied by the length was the total segment cost. Segment costs were summed over the tunnel length to produce a total estimated cost of the tunnel. Inflation and advancing technology eventually eroded the reliability of the curves, but they were a starting point for estimators in following years.

Computer methods

29. The steps involved in preparing a tunnel cost estimate with the aid of a computer are identical with those required for a manual estimate. The input data must conform to the requirements of the particular model being used. Some models have subroutines built into them that allow crew sizes, advance rates, lining thickness, and ground control measures to be calculated internally. These internal calculations may be suppressed by direct input of the required parameters, manually overriding the calculated value. Other models require that all information be input, just as in a manual estimate. Four computer models were

investigated during this study. One important aspect to remember is that although computer models unquestionably save time on computations, the data-gathering phase is not shortened and represents the bulk of the time required for tunnel estimating. Important features of each of the four models are discussed in the following paragraphs.

COSTUN - A Computer Program for Estimating Costs of Tunneling

30. COSTUN was developed in 1973 by Harza Engineering Company under contract to the Federal Railroad Administration (FRA), U. S. Department of Transportation. Complete documentation of this program is contained in Report No. FRA-ORD&D-74-16 (Wheby and Cikanek 1973). The report is available through the National Technical Information Service, Springfield, Virginia 22151. Permission by the FRA to use excerpts from this report is gratefully acknowledged. The COSTUN program has been used extensively by Harza in their tunnel work and has seen considerable use by the U. S. Army Engineer Division, New England, on the Park River Tunnel Project. Its use on this project was reported by Blackey (1979). EM 1110-2-502 (Dept. of the Army, OCE, 1980), Part II, Chapter 14, presents a method for making rough planning estimates for tunnels. The cost calculations were based on cost curves for different size tunnels and various geologic conditions developed using the COSTUN program. The method described herein allows the user to develop a more comprehensive and accurate estimate. It must be remembered, however, that the accuracy of any estimating method depends on the accuracy of the required input data.

Program philosophy and general characteristics

31. The documentation report (Wheby and Cikanek 1973) states that the program's philosophy is to duplicate the thought and reasoning processes that take place in the detailed planning, design, quantity take-offs, and estimate of cost of an actual tunnel and shaft system. To achieve this goal, construction operations that affect cost were divided into twelve components:

- a. Excavation setup.
- b. Excavation.
- c. Muck loading.
- d. Muck transporting.
- e. Muck hoisting.
- f. Muck disposal.
- g. Supports.
- h. Lining.
- i. Lining formwork.
- j. Grouting.
- k. Pumping.
- l. Air conditioning.

Each of these cost components was subdivided into labor, materials, and equipment cost subcomponents. Tunnels and shafts are considered separately in the program, but a similar division of cost components applies. The program was intended to have general application; therefore, fixed values were not assigned to these project dependent components. Rather, matrices of unit costs were developed for each component and subcomponent over a wide range of tunneling conditions, and equations were fit to these matrices and programmed. These unit costs were developed by studying past tunnel jobs, as well as current practices, and assuming synthetic organizations of men and equipment for various types and sizes of tunnel-shaft systems. Unit costs were based on 1969 Chicago prices for labor, equipment, and materials. Therefore, adjustments must be made for other times and locations. These cost adjustment factors must be provided by the user (guidelines are given herein) and consist of adjustments for labor, materials, equipment, and regional productivity differences. In addition, contractor's profit and overhead are required user input. The program does not consider the cost of any aboveground operations except cut and cover construction. Consequently, the costs of access roads, foundation underpinning, portal excavation, mitigation costs for loss of business revenue, traffic detours, right-of-way acquisition, and utility relocations must be separately calculated and added to the COSTUN estimate. Likewise, costs of architectural finish,

lighting, permanent ventilation, long-term pumping, and roadway or track construction must be separately estimated, where applicable, and added to the estimate. Since these costs and mobilization and demobilization costs may be quite significant, COSTUN is not recommended for estimating small jobs. In addition, COSTUN estimates would be inapplicable to one-of-a-kind jobs where innovative or unique equipment or techniques were used, for which there was no precedent when COSTUN was developed. In its defense, however, manual estimates for these jobs would probably be only slightly more accurate because they too base advance rates on assumptions from precedents.

32. Factors affecting the cost of a tunnel were grouped into three broad categories:

- a. Site characteristics.
- b. Design requirements.
- c. Construction methods.

The variable factors within each category must be assigned values that form the input data. Input data for a tunnel-shaft system are stored by tunnel reach and segment numbers and shaft and segment numbers. A reach is defined as any number of contiguous segments driven from a single heading. (The number of reaches is equal to the number of faces worked.) A segment is defined as a continuous length of tunnel or shaft, within which all the factors affecting cost must be constant. The user must decide when the values of a particular factor may be averaged over a given distance and when a new segment must be created.

33. Design requirements and construction methods change abruptly when they change at all, so there is no problem in assigning segment limits based on these categories. However, site characteristics are seldom constant over any appreciable distance. Judgment and experience are necessary to determine what constitutes significant change in a factor or factors, requiring establishment of a new segment. A relatively small change in some factors, such as rock quality designation (RQD), would necessitate a new segment. Changes in other factors, such as density, are not so critical, and moderate ranges of density may be averaged within a segment. As part of this study, the impact on estimated

costs resulting from varying the input values of particular factors was examined for an expected range of values while holding all other factors constant. This sensitivity analysis provided insight into which factors were critical, requiring reliable quantitative determination, and which factors could be estimated with minimal effects on cost if the estimates were wrong.

Site characteristic factors

34. Some input factors are not required for certain tunnel types and excavation methods. Other factors, identified as optional input, may be input, or the user can allow the computer to calculate the values. Guidance on selection of parameter values is given in the documentation report (Wheby and Cikanek 1973). The required factors are as follows:

- a. Rock quality designation, RQD (Deere et al. 1969).
- b. Rock strength, unconfined compressive strength, psi, of intact specimen.
- c. Governing shear strength, psf (the material strength that controls its behavior).
- d. Saturated unit weight of soil or rock, pcf.
- e. Soil angle of internal friction, PHI, undrained.
- f. Soil cohesion, C, psf, undrained.
- g. Equivalent angle of internal friction, PHIEQ, for materials characterized by friction and cohesion.
- h. Effective grain size, D_{10} , mm.
- i. Groundwater elevation - average elevation of groundwater table for each segment.
- j. Sound rock elevation - the level below which the material in a cut and cover tunnel can be removed only by drill and blast methods.
- k. Segment depth, ft, from average ground surface elevation to average tunnel elevation.
- l. Impervious layer elevation - elevation of clay layer below which ground cannot be dewatered by pumping, or below which ground is sound rock.
- m. Permeability, cm/sec, for soft ground and cut and cover segments.
- n. Inflow, gpm, at the working face.

- o. Distance to disposal, miles from exit shaft.
- p. Cost of disposal site, dollars per acre.
- q. Rock or soil temperature, degrees Fahrenheit.
- r. Air temperature, degrees Fahrenheit.

Design requirement factors

35. Required input factors are listed below with options under the factors. The reader is again referred to the documentation report for complete descriptions and definitions.

- a. Tunnel or shaft type.
 - (1) Underground heading.
 - (2) Cut and cover.
- b. Shape.
 - (1) Circle.
 - (2) Horseshoe.
 - (3) Baskethandle (shape similar to horseshoe but with height approximately one-half that of same width horseshoe).
 - (4) Square.
 - (5) Single-level cut and cover box.
 - (6) Double-level cut and cover box.
- c. Size.
 - (1) Characteristic finished inside dimension. Limiting tunnel and shaft sizes that may be run on COSTUN are minimum 10-ft and maximum 40-ft finished diameters.
 - (2) Characteristic nominal excavation dimension.
 - (3) Characteristic nominal excavation dimension plus overbreak.
- d. Slope - tunnel slope up to 26 percent may be run on COSTUN (There are limits on the use of certain muck hauling methods for steep slopes; e.g., rail muck cars cannot be used if the slope is greater than 5 percent.).
- e. Hoisting height.
- f. Reach length.
- g. Side slope (for cut and cover tunnels).
- h. Stability number - based on Terzaghi's Tunnelman's Ground Classification System and stand-up time (Terzaghi 1950).

Construction method factors

36. Site characteristics and design requirements strongly influence the choice of construction methods, but some latitude exists. All

other things being equal, a contractor will choose methods with which he is familiar and that allow maximum use of equipment presently owned. Three of the factors listed below are required user input and three are optional; if no value is input, COSTUN will calculate them or use a default value, as explained below.

- a. Construction work week - optional. If no value is input by the user, COSTUN uses a 6-day, 24-hr/day work week.
- b. Soft ground stabilization method - optional. COSTUN will select the most suitable option for particular ground conditions if not input by the user.
- c. Excavation method - required input. Options are conventional (drill or blast), mole (tunnel boring machine), cut and cover, hand excavation, and ripper excavation. In soft ground, the use of a shield is assumed by COSTUN.
- d. Muck transport method - required input. Options considered are conveyor, trucks, rail cars, and combinations of conveyor and trucks. Limiting slope for the use of rail cars is ± 5 percent; if used on steeper slopes, they must be winched. Trucks cannot be used in compressed air or in tunnels with height less than 16 ft. Conveyors are permissible in all cases.
- e. Advance rate - optional input. If not input by the user, COSTUN will calculate for each segment based on advance rate equations developed from previous jobs and equipment manufacturer's specifications. Appropriate adjustments are made, based on work hours, productivity loss during start-up, or when changing methods or starting a new segment or reach. Advance rate is one of the most critical input factors affecting the final cost estimate and should be considered carefully, whether calculated by COSTUN or input by the user.
- f. Lining and support - required input. Supports are defined as the primary means of ensuring stability of the excavation. Options include rockbolts, wire mesh and shotcrete, steel sets and lagging, or segmental liners made of steel, precast concrete, or cast iron for underground headings. For cut and cover construction, slurry walls or soldier piles and lagging may be used. Lining is the secondary support. Its purpose is to protect the primary support against deterioration, as well as to enhance hydraulic properties in water tunnels. In COSTUN, the criteria presented by Deere et al. (1969) have been adopted for support and lining design. If other criteria are used in design, the COSTUN values might not conform to actual quantities and costs. Equations used by COSTUN in selecting the support and the lining type and

thickness are detailed in the text. Lining thickness and type may be input directly by the user, if desired.

37. Some factors or operations that may vary in actual tunnel construction were assumed constant based on accepted practice in 1970. These factors are discussed in detail in the documentation report and include:

- a. Method and timing of lining erection.
- b. Selection of specific equipment and production rates.
- c. Range of conditions through which various methods are applicable.
- d. Shaft inflow control methods.

38. The tunnel program philosophy and general structure have been presented. Actual user instructions for preparing a computer tunnel cost estimate using COSTUN are presented in Appendix A.

TCM - Tunnel Cost Model

39. The tunnel cost model (TCM) was developed in 1973 in its first phase* by researchers in the Civil Engineering Department at Massachusetts Institute of Technology (MIT) for the National Science Foundation's RANN (Research Applied to National Needs) Program. Permission by Dr. Michael Markow, MIT, to summarize the project's development is gratefully acknowledged. Complete documentation of the development, applications, and user instructions is contained in a comprehensive series of MIT publications.

Program philosophy and general characteristics

40. TCM is a rather large computer program, written in PL/I (IBM Machine Language I), and is run on an IBM 370/168 at MIT. Reported storage requirements range to 500K for the largest tunnel modeled. Subroutines accompanying TCM require region sizes up to 600K in which to compile.

* A more comprehensive version was developed by Moavenzadeh and Markow (1978). Reported changes and improvements are discussed in this report in the sections in which they apply.

41. The "Summary Report" (Moavenzadeh et al. 1974a) states, "TCM was developed in an attempt to improve the assessment of uncertainty in rock tunnel cost estimates." All tunnel estimators try to assess risk and uncertainty on a job; their method usually consists of comparing the current job with similar previous ones, detailed assessment of plans and specifications, and using their experience and intuition to make subjective judgments about job risks. The philosophy behind TCM was to provide a method to quantitatively assess the impact of each item of uncertainty on costs and time. To achieve this goal, the model incorporates probability and statistics concepts that allow the user to subjectively specify the degree of confidence he has in each piece of input data. For example, instead of drawing up one geologic profile with fixed values of strength, RQD, etc., for each rock unit, the user may supply several possible values for each parameter used to describe a particular rock unit, with corresponding subjective probabilities assigned to each value. The computer model consists of three main components:

- a. A geological submodel.
- b. A tunnel simulator.
- c. A construction submodel.

Geological submodel

42. The geological submodel stores input data according to the tunnel segment and rock unit. Unlike other computer models, more than one rock unit or type may be assigned to each segment. Each rock unit must be assigned a probability of occurrence. Typically, seven parameters may be used to describe each rock unit, such as rock type, major defects, RQD, foliation, gas, water inflow, and compressive strength.

43. Fewer or more parameters may be used as the user sees fit to describe the rock unit. This flexibility in segment and rock unit descriptions is made possible through the use of "parameter trees," as shown in Figure 1. Typical values, possible states, and construction consequences are presented in Table 1 for parameters typically used to form parameter trees.

44. In addition to the probabilistic states assigned to segments, the physical boundaries of the segments within which these states are

P(SHALE 1) = 0.2
P(SANDSTONE 1) = 0.8

P(SHALE 2) = 0.4
P(SANDSTONE 2) = 0.6

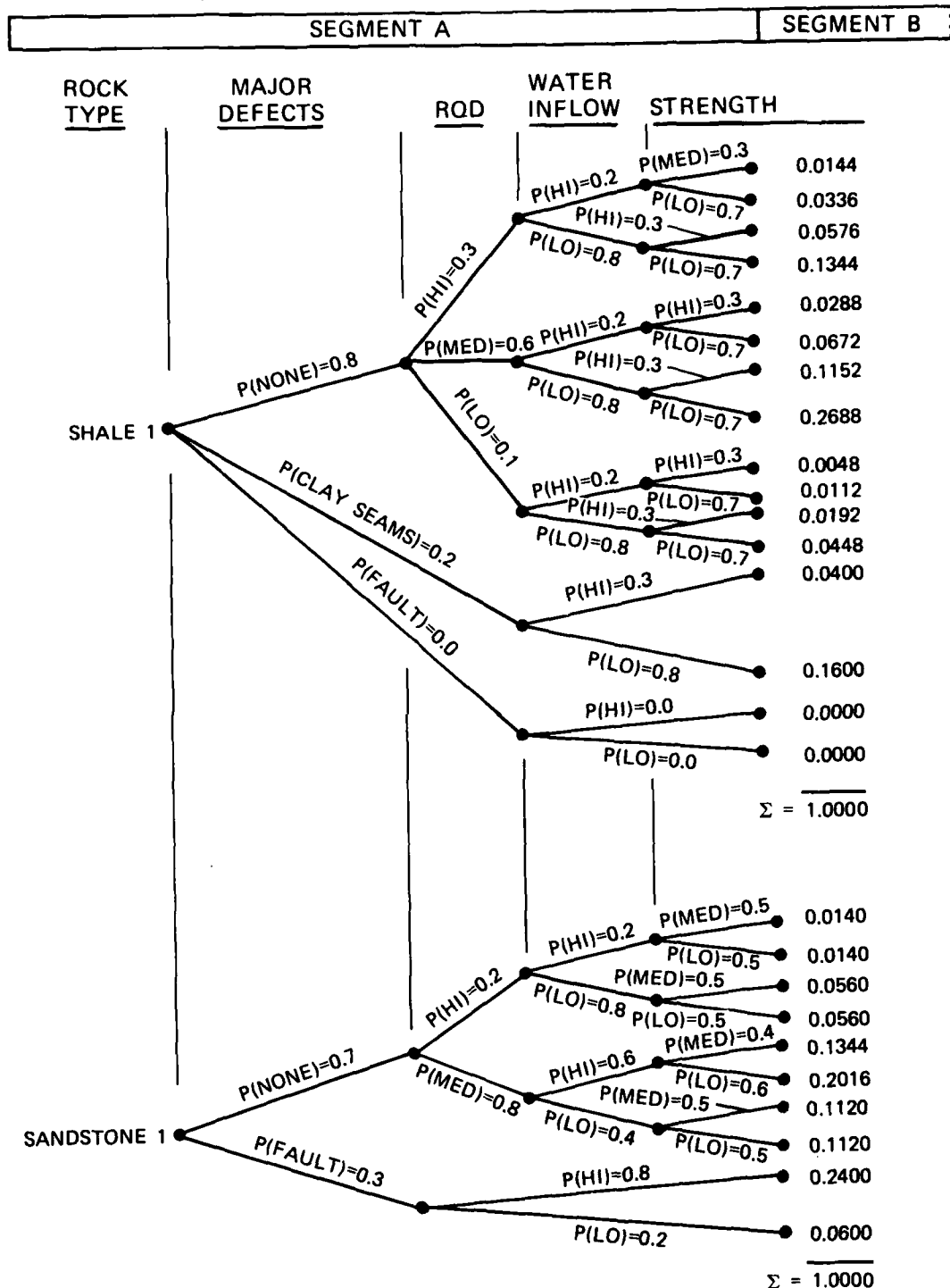


Figure 1. TCM parameter tree

valid must be identified in the input data. The process of defining segment limits and rock units within segments is interdependent. Regardless of the number of rock types possible within a segment, the sum of the probabilities of occurrence of each unit must be 1.0. For the example shown in Figure 1, the probability of encountering shale 1 in segment 1 is set at 0.2 and the probability of encountering sandstone 1 in segment 1 is 0.8. In addition, the sum of the probabilities of the right end nodes of each parameter tree must be 1.0. The extreme right node probabilities of parameter trees are obtained by cumulative multiplication of the probabilities along each continuous branch. For example, the probability of encountering shale 1 in segment 1 with no major defects, medium RQD (30-70 percent), low inflow, and low strength is given by

$$P(\text{Shale 1}) \times P(\text{No Defects}) \times P(\text{Med RQD}) \times P(\text{Low Inflow}) \times P(\text{Low Strength})$$

which for the example in Figure 1 is

$$\begin{aligned} P &= 0.2 (0.8 \times 0.6 \times 0.8 \times 0.7) \\ &= 0.2 (0.2688) = 0.0538 \end{aligned}$$

A new parameter tree must be created for each rock unit within the segment. In the simplified example shown, only two rock units were considered within segment 1; the most likely unit was sandstone with a probability of 0.8 and the least likely ($P = 0.2$) was shale. Thorough guidelines for forming segments and parameter trees are given by Vick (1974), Moavenzadeh (1974b), and Reynoso (1976). The interested reader is referred to Benjamin and Cornell (1970) or Blum and Rosenblatt (1972) for a more comprehensive treatment of probability and statistics for decision making.

45. New tunnel segments must be created when the user wishes to change the set of geological states or associated probabilities of the states. Segments may be independent, partially dependent, or completely dependent. Complete independence is assigned to segments modeled without consideration of rock types assigned in adjacent segments. Complete dependence is assigned to segments whose parameter trees are totally dependent on those of adjacent segments. The most general case, partial

dependency, is modeled using Markov dependency tables. This case would be appropriate for modeling the occurrence of a fault, for example, where the user feels that if the fault is encountered in a given segment, there is an increased (or decreased) likelihood of the fault extending into the next segment. The interested reader is referred to Barucha-Reid (1960) or Stark and Nicholls (1972) for the theoretical development and applications of Markov processes. After assimilating the parameter trees and Markov tables for segment relationships, the geological model produces and stores a user-specified number of profiles to be used by the tunnel simulator to produce estimates.

Construction submodel

46. This component calculates unit times and costs of each construction operation modeled, based on supplied input values of construction variables. Major features and functions of the submodel are:

- a. Scheduling procedure - to specify the number and locations of headings and timing of operations at each heading.
- b. Model of construction elements - to describe the excavation, support, dewatering, probe drilling, and lining cycles and interactions.
- c. Construction method specification - to specify the methods to be used for particular geological conditions and for each heading worked.
- d. Construction parameter specification - to input unit costs, times, productivity rates, and other related data.
- e. Simulation routines - to compute cycle times and costs for each geological condition considered.

Cycles are calculated for excavation, mucking, muck hauling, muck hoisting, support installation, pumping, grouting, probe drilling, and lining. Aboveground costs are not considered by the simulation routines. When modeling multiple headings, construction operations are assumed to be independent. This assumption is usually acceptable unless alternating faces are worked from the same exit shaft or adit.* The model calculates approximate mobilization time and cost. It does not consider

* The latest version of TCM incorporates provisions for modeling alternating headings more realistically.

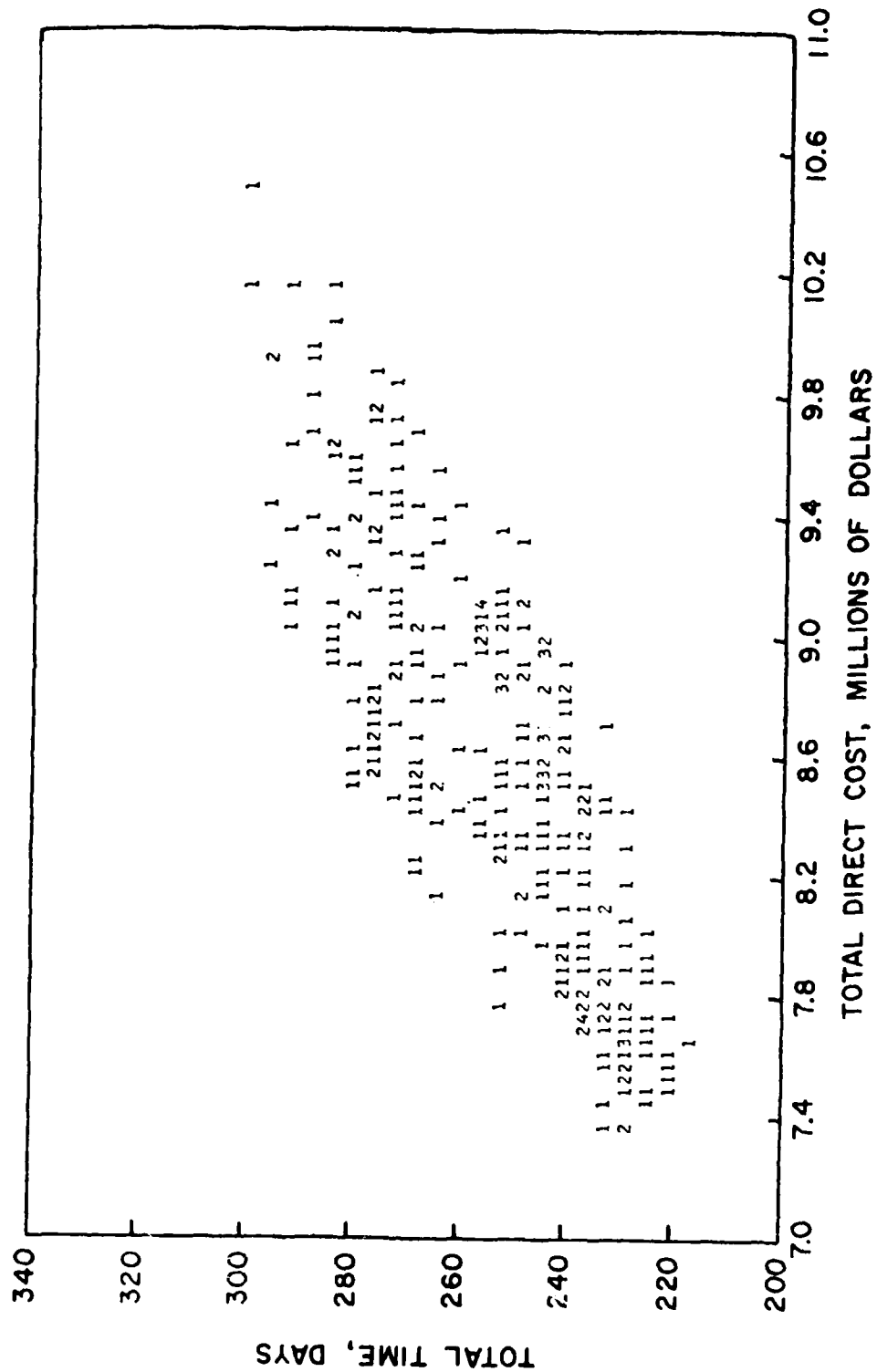
permanent pumping, ventilation, architectural finish, or roadways in its cost simulation routines. The construction submodel does not rely on data files for unit costs or cycle times for any tunneling operations. All data must be supplied by the user. The amount of detailed user input is rather large. Much of these data could be assembled only by an experienced estimator team. Owners or planners would quite likely have problems supplying some of the required input. These data are assigned values for worst case, best case, and expected case. In addition, the distribution that describes the data may be normal, beta, or uniform. After all user input has been assimilated, the construction submodel computes cycle time and costs for each construction operation modeled.

Tunnel simulator

47. The tunnel simulator combines the profiles produced by the geological submodel with the calculated cycle times and costs for each geological state and construction method produced by the construction submodel to calculate the total time and cost required to construct the tunnel through each of these profiles. The results are plotted in a scattergram such as Figure 2. It also produces a series of progress reports showing detailed advance of tunnel operations at different times. An optional file can be used to store individual simulations (each simulation constitutes one tunnel estimate). The individual results can be printed out and used in statistical analysis routines to calculate expected cost, standard deviation, etc.

User instructions

48. As mentioned earlier, TCM is a rather large and complex computer program and requires a computer with large storage capacity. Because of its size and the fact that it is written in PL/I, it was considered impractical to adapt it to the WES computer system. The only installation known to the author that currently has an operating version is MIT, and TCM is operational on the IBM 370/168 at MIT. Computers exist within the Corps and with contract vendors that could accommodate the program. However, to convert the program to Fortran IV, the computer language most familiar to noncomputer specialists, would essentially require writing a new program patterned after TCM, which probably would



not be as flexible and comprehensive as the MIT version. The interested reader can secure a comprehensive user's manual (Reynoso 1975) from MIT. Therefore, instructions for using TCM are not presented in this report.

Applications

49. The program developers reported the use of TCM to prepare estimates of several tunnels (Minnot 1974 and Wyatt 1974). Normal practice was to perform several hundred simulations for each tunnel to cover all situations. The scattergrams of costs and time were then statistically analyzed to yield the expected cost and time, worst and best cases, etc. A detailed comparison of TCM estimates and actual costs was not presented in the MIT series. However, for the Harold D. Roberts Tunnel in Colorado, estimated advance rates varied significantly from actual rates. These differences were attributed to discrepancies between actual geology and model input describing geology (Wyatt 1974).

TM - Performance/Cost Tunneling Model

50. The performance/cost tunneling model (TM) was developed by General Research Corporation for the Advanced Research Projects Agency/Bureau of Mines program in rock mechanics and rapid excavation. Its development and application are discussed by Pietrzak et al. (1972) and Hibbard et al. (1971).

General philosophy

51. In general, the program philosophy lies somewhere between COSTUN and TCM. COSTUN employs empirical equations based on regression analysis of previous tunnel jobs to determine support requirements, dewatering requirements, advance rates, etc. (There are provisions for the user to override the calculated values by supplying parameter values he thinks are more appropriate). Also, COSTUN employs a fixed geology model. The TCM program models uncertainty in its geology and construction submodels. All variable parameters affecting tunnel construction must be input by the user. In addition, the user must supply subjective probability of the occurrence of each variable state modeled.

Geology submodel

52. TM employs a user specified geology model (uncertainty is not accounted for) similar to COSTUN, with the added capability of modeling geology in three dimensions or using familiar 2-D profiles. The geology model does not consider soil profiles or mixed face. For each rock stratum, the model generates a file of material properties including density, RQD, abrasiveness, unconfined compressive strength, water inflow, and rock temperature. Parameter values are supplied by the user for each tunnel segment.

Tunneling submodel

53. The tunneling submodel simulates construction operations and conditions. The model can simulate various full-face rock excavation methods, including innovative techniques, but must be supplied with very detailed input to describe all relevant parameters. Soft ground, cut and cover, and mixed face cannot be simulated by TM. Likewise, shafts, portals, adits, and aboveground costs are not considered. Permanent pumping, roadbed or track, permanent lighting, and other architectural finish items are also omitted from consideration. Advance rates are computed using preprogrammed empirical relationships developed from a study of case histories. Construction progress reports are printed during simulation at user-specified time intervals. These status reports could be valuable aids for monitoring progress and costs and correcting problems as they occur. Information printed out includes heading position, elapsed time, average advance rate, availability, and utilization factors for each construction operation (excavation, support, dewatering, etc.).

Cost submodel

54. The cost submodel uses the input unit cost values for labor, materials, and equipment, the calculated quantities, advance rates, support requirements, dewatering and air conditioning requirements, etc., to calculate and tabulate costs accrued for each tunnel increment (measured in time, not distance). Profit and overhead, which are input by the user, are added to the costs. Cost status reports are printed for the same time intervals as the performance reports, including the cost and time of the completed tunnel.

Applications

55. The developers of this model report good correlation of calculated and actual values of advance rate, total time of construction, and cost for the Layout Tunnel. This tunnel, built in 1971-72 as part of the U. S. Bureau of Reclamation (USBUREC) Strawberry Aqueduct System, is approximately 3-1/4 miles long and 13 ft in diameter. It was moled through hard sandstone and conglomerate. The model is well suited for comparison of alternatives, but its use for detailed estimates is hampered because of the large storage requirements and detailed and extensive input data requirements.

TSC/FMA - Transportation Systems Center/Foster Miller Associates Model

56. The Transportation Systems Center/Foster Miller Associates (TSC/FMA) computer model was developed in 1979 through a cooperative effort of the Underground Technology Development Corporation and SKNH Company, under the sponsorship of the Urban Mass Transportation Administration (UMTA), United States Department of Transportation (USDOT). Complete documentation of the development and application of the model is contained in a report by Foster et al. (1979). Copies are available from the National Technical Information Service, Springfield, Virginia.

General philosophy

57. The program is run on a Wang Model 2200 computer. Data files are stored on discs. The model consists of two main data bases and supporting computations. Data Bank 1 contains factors that describe the amount of effort required to accomplish each unit operation. Data Bank 2 contains unit costs of labor, equipment, and materials required. Unit effort data were developed from analysis of 20 soft ground transit tunnels built in the United States in the last 10 years. The model is applicable to soft ground transportation tunnels and stations. Base or reference unit cost data reflect conditions prevailing in Washington, D.C., in January 1976. Costs for other times or regions may be adjusted using inflation factors similar to the method used with COSTUN, or the

actual unit costs may be determined and used in Data Bank 2. Only excavation and lining for soft ground transit tunnels are considered in the present version, although the developers report that it will be revised to make it more comprehensive as data on other operations are developed.

Applications

58. The model has been used on three sections of the Washington Metropolitan Area Transit Authority (WMATA) subway system. Section 1 consisted of 5393 ft of concrete-lined tunnel driven through moderate ground requiring some stabilization, an 800- by 75-ft station, and four vent and fan structures. The section actually analyzed was 2996 ft of tunnel, excavated by a backhoe digger arm under a shield. The actual construction costs were \$5,837,000. The FMA estimate was \$6,345,000, or 8.7 percent above actual cost. For the tunnel only, actual costs were \$4,445,000, and the model estimate was \$4,332,000, or 2.5 percent below actual cost.

59. Section 2, consisting of 8820 ft of tunnel, was driven through difficult ground and passed beneath several bridge piers and abutments. Excavation was accomplished by a backhoe digger arm under a shield. Steel segments served as both primary support and final lining. The actual project costs were \$33,373,000 for those items considered by the model, which estimated the costs at \$31,017,000, or 7.1 percent lower. For tunnel excavation, lining, backfill, and grouting, the actual costs were \$25,721,000, and the model estimate was \$24,648,000, or 4.2 percent lower.

60. Section 3 comprised 8115 ft of concrete-lined tunnel, an 800- by 75-ft cut-and-cover station, and six vent and fan structures. The section actually analyzed was 3803 ft long. Excavation was accomplished with a wheel excavator through good soft ground. Support was provided by expanded ring beams and wood lagging. The actual cost for the analyzed section was \$6,443,000, and the model estimate was \$6,731,000, or 4.5 percent higher. For tunnel costs only, the actual cost was \$4,603,000, and the model estimate was \$5,044,000, or 9.6 percent higher.

61. These results indicate that for its intended applications, the model provides estimates that are within 10 percent of actual costs,

provided there are good definitions of geology, excavation methods, and support requirements.

User instructions

62. Complete instructions for using the TSC/FMA model are available from the Transportation Systems Center, Department of Transportation, Cambridge, Massachusetts. Therefore, instructions are not repeated in this report.

Comparison of Computer Models, Cost Curves, and Manual Estimates

63. The investigation of the steps involved in estimating tunnel costs using all the methods described above clearly indicated that there is no one best method for all purposes. The choice of method must be based on the end use of the estimate. Detailed manual estimates for final design, contract documents, and contractor bids are probably here to stay. Cost curves or unit cost estimates may be useful for preliminary estimates and comparison of alternatives. Computer models may be used to good advantage for preliminary planning estimates, evaluation of alternatives, checks on manual estimates, and monitoring progress. Table 2 presents the relative advantages of the four models investigated during this project. One of the objectives of the project was to develop or adapt cost-estimating aids that planners not intimately familiar with tunneling could use. All things considered, COSTUN meets these criteria better than any of the other models studied. Therefore, it was selected for in-depth analysis, using collected tunnel case histories.

PART III: ANALYSIS OF CASE HISTORIES

64. One of the problems in this study was obtaining case histories of tunnels with sufficient information to: (a) allow a meaningful comparison of the reliability of manually prepared cost estimates with those generated by the computer program COSTUN, (b) allow a meaningful comparison of estimated and as-built costs, and (c) identify the factors responsible for overruns between estimated and as-built costs. After much studying and then discarding of several cases where complete documentation was unavailable, three tunnels were chosen that had good documentation of geology, design, construction methods, and estimates. The following paragraphs present brief descriptions of each tunnel, followed by an analysis of estimated and as-built costs and factors responsible for the differences between the two.

Nast Tunnel

65. Nast Tunnel was the first tunnel in the United States to be driven through granite with a boring machine (Larson 1975). Moles were thought to be unsuitable for hard rock tunnels prior to this job because of high cutter bit replacement costs. Indeed, on this job cutter bit costs amounted to over \$1,200,000 on a winning bid price of approximately \$6,800,000. Nast Tunnel is a 15,653-ft-long, 10-ft-diam water tunnel that was designed by the USBUREC and built between 1970 and 1973 in Pitkin County, Colorado. On this job contractors were allowed to bid on a drill and blast schedule and an alternative mole-driven tunnel option. Nine bids were received, six on the drill and blast schedule and three on the mole schedule. The winning contractor bid about the same amount on both options. The award was made for the schedule using the boring machine, and a Memorandum of Understanding was executed that permitted the contractor to change from mole driven to drill and blast at his option. Approximately 85 percent of the tunnel was moled; 15 percent was conventionally driven through reaches of poor quality rock.

66. All information used to develop and compare cost estimates of Nast Tunnel was provided by the USBUREC Engineering and Research Center, Denver, Colorado. Their cooperation is gratefully acknowledged. Table 3 summarizes the cost estimates prepared by the engineer, various contractors, and the COSTUN computer model. All identifiable costs not considered by the computer model were subtracted from the total bids so that a meaningful comparison could be made. Engineer estimate 1 and contractor bids 1-6 were for the conventional or drill and blast excavation schedule. Engineer estimate 2 and contractor bids 7-9 were for the mole excavation schedule. Contractor bids 1 and 7 were submitted by the same contractor, and the bid price for either option was about the same. Furthermore, when all schedule items were included, the bid prices were identical for both options. This contractor was awarded the contract, although one other bid, No. 8 in Table 3, was apparently lower. However, when the excluded costs were added back, this bid was higher than the winning bid. The winning bid was approximately 33 percent higher than the engineer estimate for either excavation option. The highest bid was nearly double the engineer estimate. There was a 45 percent spread between the winning and the highest bid.

67. COSTUN estimates 1-9 were prepared using information available at bid time. COSTUN estimate 1 represents the estimated construction cost for the most likely tunneling conditions, using mole excavation when feasible and drill and blast excavation in poor rock zones and near the inlet and outlet portals. The support and lining types and amounts used for this estimate were those called for in the plans and specifications. The total estimated tunnel costs for this run were \$7,089,000, or 5 percent above the winning bid of \$6,763,000 and 38 percent above the engineer estimate. COSTUN estimates 2-9 could be called "what if" estimates, in that the major input factors believed to affect construction costs were individually examined while holding all other variables constant at the expected value. Pessimistic and optimistic values were assigned to each of the major variables for each tunnel segment and reach. Some of these estimates reflected genuine uncertainty while others were used to test the sensitivity of costs to changes in a

specific variable. For example, runs 2 and 3 were made to determine the construction cost impact of varying rock strength. The actual rock strengths were known within reasonable limits from lab tests and empirical correlations, but studies have shown that stand-up time, advance rate, mole cutter bit wear, drill steel life, etc., are at least partially dependent on rock strength, among other things.

68. In run 2, the rock strengths input were 25 percent higher than expected strengths. For most types of structures, an increase in strengths is welcomed, but not necessarily for tunnel excavation. Higher strengths are associated with the harder crystalline rocks that are more abrasive. The results are higher cutter bit wear, more drill steel breakage, and overall slower advance rate, leading to increased costs. For this tunnel, the estimated consequences were nearly \$500,000 (6 percent) and 100 working days (10 percent) over the estimate for most likely conditions. Run 3, which used strengths 25 percent lower than expected, resulted in estimated cost and time savings of \$450,000 (6 percent) and 102 working days (10 percent) less than the estimate for most likely conditions.

69. The impact of variation in rock quality was assessed in runs 4 and 5. These runs reflected genuine uncertainty in the expected rock joint frequency, joint conditions, and degree of weathering for which the borehole data were lacking. In fact, change order No. 8, which provided for additional payment to the contractor of \$767,000, was directly related to the occurrence of a major shear zone approximately 1700 ft long, which had not been detected by surface mapping or borings. The tunnel boring machine had to be moved back and the heading was advanced through this reach by the drill and blast method, using closely spaced heavy steel sets for support. In run 4, pessimistic values of RQD, approximately 33 percent lower than the expected values, were used. Estimated construction time increased 22 percent to 1203 days, or 218 days more than the expected time of 985 days. Estimated costs rose to \$8,264,000, or 17 percent above the \$7,089,000 expected cost. In run 5, RQD values 33 percent higher than expected were input. The estimated cost reduction was \$718,000 (10 percent), while the time was cut 12 percent to 865 days.

70. In runs 6 and 7, the cost/time impact of reducing and increasing, respectively, the lining thickness by 30 percent of the design value was assessed. The specification of lining thickness is of major importance to the cost of a tunnel. The quantity of concrete that must be placed obviously increases for conservative (thicker) lining specifications. Additional cost and time penalties occur because the volume of rock that must be excavated increases proportionately. The larger the tunnel diameter and length, the more serious are the consequences. Compounding this problem is the lack of understanding of interaction between rock load and deformation and transfer of the load to the lining and support.

71. For a reduction of 30 percent in lining thickness (run 6), estimated costs were reduced by \$527,000 (7 percent), and construction time was reduced by 30 days (3 percent) over the length of the tunnel. This reduction represents a \$33/ft saving over the design lining thickness. A 30 percent increase in lining thickness (run 7) resulted in a 7 percent (\$484,000) increase in cost and a 2 percent (24 days) increase in construction time.

72. Computer estimates 8 and 9 were made to study the impact of rock temperature in the tunnel. As expected, the results of these runs indicated that for the range of temperatures expected in Nast Tunnel, there was no effect on cost. In deep tunnels with higher temperatures, the cost of ventilation and air conditioning increases, but for shallow tunnels, such as Nast, there seems to be no effect.

73. The final cost for Nast Tunnel was \$7,473,000, including change orders for differing site conditions and other unforeseen problems. This sum excludes those costs not considered by COSTUN, such as access roads, drainage ditches, the Fryingpan Conduit, and the Granite Adit portion of the job. Granite Adit is a 10-ft-diam, 777-ft-long tunnel intersecting Nast Tunnel about 4000 ft from the inlet portal. Its purpose was to convey water from Granite Creek to Nast Tunnel. During construction, it was used as an exit for muck hauling and disposal for the reaches of tunnel adjacent to it. Fryingpan Conduit is a 1500-ft-long conduit constructed of 7-ft-diam precast concrete pipe,

connecting Nast Tunnel at the outlet portal to Boustead Tunnel's inlet portal, which is a diversion tunnel through the Continental Divide.

74. The COSTUN as-built estimate totalled \$7,691,000, or 3 percent above the actual cost. The changes made between the COSTUN preconstruction estimate using most likely conditions and the COSTUN as-built estimate included the allowance for the 1700-ft shear zone and a smaller shear zone approximately 300 ft long, both of which caused a change from mole excavation to the drill and blast method. In addition, one segment approximately 4000 ft long that ran under a small lake experienced minor water inflows, but the resulting cost increase was insignificant.

75. Table 4 contains a breakdown of COSTUN estimates 1-9 and the as-built estimate for labor, equipment, and materials components and the totals. Also shown is the total time required for construction of the tunnel for each estimate. Labor was the major cost component for this job and most tunnels, accounting for two thirds of the total for all estimates. Equipment and materials were nearly equal, averaging 16 and 17 percent, respectively, of the totals. Foster et al. (1979) indicate that a breakdown of 40 percent for labor, 40 percent for materials, and 20 percent for equipment is reasonable. Because tunnel jobs vary so widely in nearly all aspects, no significance should be attached to these figures for tunnels in general. The engineer estimates and contractor bids were not itemized for labor, equipment, and materials, so there is no basis for comparison of COSTUN figures except for the totals shown in Table 3. These figures show that the COSTUN best estimate of actual conditions was 5 percent above the winning bid. The COSTUN as-built estimate was 3 percent higher than the actual cost. These figures indicate very good correlation, but they do not give the total picture. The multitude of factors used to arrive at the estimated totals may or may not represent actual conditions. For example, the profit and overhead factors represent a combined 30 percent of the totals in the estimates. The actual profit and overhead, as well as the figures used in the bid, are unknown. Therefore, the reader is cautioned that although the overall accuracy of the estimates looks good, the accuracy of individual factors may not have been as good. The self-cancelling nature of random errors in these factors could still result in a balanced total estimate.

Buckskin Mountains Tunnel

76. Buckskin Mountains Tunnel, a 6.8-mile-long, 22-ft-diam irrigation tunnel, was designed by USBUREC and built near Parker, Arizona, as part of the Central Arizona Project. Prospective bidders were allowed to bid on three alternatives: (a) a 19-ft 6-in.-diam, drill and blast horseshoe-shaped tunnel; (b) a 20-ft-diam, circular-moled tunnel with cast-in-place concrete lining; and (c) a 22-ft-diam, circular-moled tunnel with a precast concrete segmental lining. The award was made for the 22-ft-diam tunnel, and construction began in 1975. The tunnel was holed through in May 1979, but final cleanup has not been completed at the time of this report. A Robbins mole was used for the entire length, except for approximately 100 ft at each portal excavated by drill and blast. The tunnel support and lining consist of 6-in.-thick precast concrete segments, installed just behind the mole. The tunnel was driven through competent andesite, but some blocky conglomerate was encountered that slowed progress. A \$6-million changed conditions claim concerning this blocky zone is still pending and may add to its \$60-million expected total cost.

77. Information used to develop and compare COSTUN estimates for Buckskin Mountains Tunnel was obtained from three sources: (a) the USBUREC Engineering and Research Center, Denver, Colorado, provided geology reports; (b) the U. S. Army Engineer District, Kansas City, loaned a set of job specifications, including engineer estimates and contractor bids; and (c) the personnel of the resident engineer's office, USBUREC, Parker, Arizona, provided other useful information. Table 5 summarizes the cost estimates prepared by the engineer, various contractors, and the COSTUN computer model. All identifiable costs not considered by the computer model were subtracted from the contractor bids and engineer estimates for the sake of comparison.

78. Engineer estimate 1, COSTUN estimate 1, and contractor bid 1 were for the 19-ft 6-in.-diam horseshoe-shaped tunnel on the drill and blast schedule. The engineer estimate for this option was \$53,991,000, as compared with \$51,641,000 for the COSTUN estimate and \$65,513,000 for

the lone contractor bid on this option. Engineer estimate 2 (\$47,441,000), COSTUN estimate 2 (\$53,841,000), and contractor bid 2 (\$71,208,000) were for the 20-ft-diam moled tunnel option with cast-in-place concrete lining. Both of the above options show a rather wide spread (27 and 50 percent, respectively), although the engineer and COSTUN estimates are within 5 and 13 percent of each other.

79. Engineer estimate 3, contractor bids 3-5, and COSTUN estimates 3-9 are for the 22-ft-diam moled tunnel with precast concrete segmental lining. COSTUN estimate 3 of \$59,959,000 represents the estimated cost for the most likely conditions known at bid time, which is 27 percent higher than the engineer estimate of \$47,257,000 and 33 percent higher than the winning contractor bid of \$44,940,000. The highest bid of \$63,493,000 was 41 percent higher than the winning bid, 34 percent higher than the engineer estimate, and 6 percent higher than the COSTUN estimate. The winning bid was 5 percent lower than the engineer estimate. At first glance, the COSTUN estimate seems to be far too high. However, the as-built cost of the tunnel was reported as approximately \$60 million, which lends more credence to the COSTUN estimate.

80. COSTUN estimates 4-9 were used to check the cost impact of varying input parameters, one at a time, over a range of values. For an increase of 15 percent over the most likely RQD values (COSTUN estimate 4), the estimated cost was reduced to \$52,287,000, or 13 percent below the estimate for most likely conditions. A 15 percent decrease in RQD values in COSTUN estimate 5 produced an expected cost of \$75,130,000, or 25 percent higher than the \$59,959,000 expected cost for most likely conditions. In COSTUN estimates 6 and 7, the unconfined compressive (UC) strengths were increased and decreased 25 percent, respectively, from the most likely values. The resulting costs were \$72,054,000 for a 25 percent increase in UC strengths (20 percent above the \$59,959,000 for most likely conditions) and \$49,581,000 for a 25 percent decrease in UC strengths (17 percent below the expected cost for most likely conditions). The lining thickness was increased 33 percent in COSTUN estimate 8 over the actual lining thickness used in construction (6 in.) and was increased to 10 in. (67 percent) in COSTUN estimate 9. These runs produced

estimates of \$61,373,000, or 2.4 percent above the total cost for the actual lining thickness used, and \$62,826,000, or 4.8 percent higher, respectively. The increase in cost per linear foot of tunnel over the actual lining thickness amounted to \$39 and \$41, respectively, on a base cost of \$1670/ft.

81. The as-built cost of Buckskin Mountains Tunnel was reported as \$60 million in round figures. The COSTUN estimate representing conditions known at the end of construction totalled \$61,474,000, or 2.5 percent above the actual cost. However, as mentioned earlier, a \$6-million claim for changed conditions is pending and may add to the total cost. Even if the entire \$6 million is awarded to the contractor, the COSTUN estimate would be only 7 percent below total cost. Thus, the COSTUN as-built estimate falls within the range of accuracy of -7 to +2.5 percent. Again, although the overall accuracy of the total cost figures looks good, the accuracy of individual components may not be as good. For example, the engineer estimate for excavation in the tunnel was \$29,589,840, while the COSTUN estimate for this work was \$38,495,000, or 30 percent higher. This difference is consistent with the overall spread between the engineer and the COSTUN estimate of 27 percent, cited earlier. However, the engineer estimate for furnishing and installing the segmental lining was \$16,972,000, while the COSTUN estimate was \$17,267,445, or 1.7 percent higher. These component costs compare favorably, but the 27 percent spread between the estimated totals is not reflected. Obviously, the difference had to be greater among the remaining component costs in order for the total 27 percent difference to be achieved.

82. Table 6 presents the breakdown of estimated costs for labor, equipment, and materials and the estimated time for construction of the tunnel for COSTUN estimates 1-9 and the COSTUN as-built estimate. The average cost of labor amounted to 60 percent of the total, while the equipment accounted for 22 percent and materials accounted for the remaining 18 percent for the 10 estimates.

83. The estimated time required to complete the tunnel ranged from 2475 to 4095 days for the three options under most likely conditions.

These figures contrast sharply with the allotted contract time of 1800 days, which the contractor met. The reasons for this discrepancy in estimated times could not be determined. Again, this case shows that even when the estimated totals agree closely, there can still be large differences in some factors or components. It is interesting to note that the least expensive alternative according to the COSTUN estimates was the 19-ft 6-in.-diam, horseshoe-shaped drill and blast option at \$51,641,000, while the 20-ft-diam, circular-moled tunnel was second at \$53,841,000 and the 22-ft-diam moled tunnel was the most expensive at \$59,959,000. The engineer estimates are exactly reversed, with the 22-ft-diam tunnel the least expensive and the 19-ft 6-in.-diam tunnel the most expensive tunnel option.

Park River Tunnel

84. Park River Tunnel is a 22-ft-finished-diam, 9095-ft-long Corps of Engineers tunnel, that is located approximately 150 ft below street level in Hartford, Connecticut, and was designed to convey flood flows of the Park River to the Connecticut River. It passes through sandstone and shale, most of which is of good quality. One shear zone approximately 270 ft long was encountered, as predicted by exploratory borings. Prospective bidders were allowed to bid three alternatives for driving the tunnel: drill and blast excavation with a cast-in-place concrete lining, mole excavation with cast-in-place concrete lining, and mole excavation with a precast segmental concrete lining. The award was made for the mole-driven tunnel with precast segmental concrete lining. Construction began in 1977, and the tunnel was holed through in July 1980. Approximately 150 ft near the outlet portal was excavated by drill and blast for a staging area for the mole, as well as approximately 270 ft of shear zone.

85. Information used to develop and compare COSTUN estimates for Park River Tunnel was furnished by personnel of the U. S. Army Engineer Division, New England. Table 7 summarizes the cost estimates and bids. Table 8 presents a breakdown of the various COSTUN estimates for labor,

equipment, materials, and time required to build the tunnel. In addition to the data used for comparison on the two tunnels previously discussed, the estimated costs are also displayed for the two shafts associated with this project (Table 7). As with the other tunnels, all identifiable costs not considered by the COSTUN model were subtracted from the engineer estimates and contractor bids for a meaningful comparison.

86. Engineer estimate 1, contractor bid 1, and COSTUN estimate 10 are for the drill and blast option. The engineer estimate for tunnel construction was \$20,916,000, as compared with the contractor bid of \$24,885,000 and the COSTUN estimate of \$19,476,000. For the inlet shaft, the engineer estimate was \$770,000, the COSTUN estimate \$1,971,000, and the contractor bid \$1,800,000; for the outlet shaft, the engineer estimate was \$1,100,000, the COSTUN estimate \$1,981,000, and the contractor bid \$3,000,000. The total project was estimated to cost \$22,786,000 by the engineer, \$23,428,000 by the COSTUN model, and \$29,685,000 by the contractor (a spread of 30 percent).

87. Engineer estimate 2, contractor bid 2, and COSTUN estimate 11 are for the mole excavation schedule with cast-in-place lining. The engineer estimates and COSTUN estimates for the inlet and outlet shafts were unchanged, while the contractor bids were \$3,500,000 for the inlet and \$3,000,000 for the outlet shaft. The tunnel construction was estimated at \$17,977,000 by the engineer, and \$16,785,000 by COSTUN, as compared with the contractor bid of \$14,096,000. Since the contractor bids for the shafts were much higher than either estimate and the bid for tunnel construction was much lower, this imbalance might have been a strategy to increase early cash flow. The estimates and bids for the total project were \$19,847,000 by the engineer, \$20,737,000 by the COSTUN model, and \$20,596,000 by the contractor (a spread of just 4.5 percent).

88. The contractor awarded the job on the mole excavation schedule with precast lining bid \$17,329,000 on the project (contractor bid 3). The bid was 3.7 percent lower than engineer estimate 3 of \$17,993,000 and 5.8 percent lower than COSTUN estimate 1 of \$18,405,000. Again, the

contractor bids for tunnel, inlet, and outlet shafts appear to be unbalanced. For the outlet shaft, from which tunnel excavation proceeded, the contractor bid was \$4,000,000, while the engineer and COSTUN estimates were \$1,100,000 and \$1,981,000, respectively. This trend is apparent in every contractor bid on the project, so a comparison of the shafts and tunnel items separately is not meaningful. Only the total project estimates are compared. The next lowest bid of \$17,360,000 was 3.5 percent lower than the engineer estimate. The highest bid of \$50,310,000 was 280 percent of the engineer estimate. The bid spread was nearly \$33,000,000, almost double the winning bid.

89. COSTUN estimates 2-9 were made to test the cost impact of varying rock properties and design lining thicknesses in the tunnel. Shaft properties and costs were held constant. In runs 2 and 3, the RQD values were increased 15 and 30 percent, respectively, over the most likely values. For the 15 percent increase in RQD, the estimated cost of the tunnel decreased to \$13,555,000, or 6.2 percent lower than the \$14,453,000 expected cost. The 30 percent increase in RQD resulted in a calculated 9.7 percent reduction to \$13,055,000. Estimated time savings were 34 days (5.6 percent) in run 2 and 53 days (8.7 percent) in run 3. RQD values were decreased in runs 4 and 5 by 15 percent and 30 percent, respectively. The resulting increases in costs were 9.7 percent to \$15,851,000 for the 15 percent decrease in RQD and 34.3 percent to \$19,406,000 for the 30 percent decrease. Estimated time penalties were 53 days (8.7 percent) in run 4 and 186 days (30.4 percent) in run 5. In runs 6 and 7, the UC strengths were increased and decreased by 15 percent, respectively. Run 6 produced an estimated cost of \$15,543,000, or 7.5 percent higher than the expected cost, while the 15 percent decrease in UC strengths in run 7 resulted in a 7.5 percent decrease in cost to \$13,360,000. The estimated time penalty for the 15 percent increase in UC strengths was 40 days (6.5 percent) in run 6, and the estimated time savings attributed to a 15 percent reduction in UC strengths was 39 days (6.4 percent) in run 7.

90. Runs 8 and 9 were made to assess the cost impact of increasing the thickness of the precast concrete segments from 9 to 12 in.

in run 8 and to 15 in. in run 9, amounting to increases of 33 percent and 67 percent, respectively, over the design value of 9 in. The cost penalty was \$650,000, or 4.5 percent, for the 12-in. liner and \$1,390,000, or 9.6 percent, for the 15-in. liner. The time penalties were 7 days in run 8 (1 percent) and 13 days (2 percent) in run 9 over the expected time of 611 days for the design lining thickness.

91. The COSTUN as-built estimate is identical with the estimate for most likely conditions known at bid time. There were no big surprises in constructing this tunnel, except for some difficulties encountered during construction of the outlet shaft. Because the tunnel has only recently been completed, final as-built costs were not available but are expected to be around \$23,000,000. If this estimate is correct, the COSTUN and engineer estimates are 20 and 22 percent, respectively, below the final costs.

92. Table 8 presents a breakdown of COSTUN estimates for labor, equipment, materials, and time required to build Park River Tunnel. Labor costs accounted for approximately 65 percent, equipment 19 percent, and materials 16 percent of the estimated total cost.

PART IV: SUMMARY AND CONCLUSIONS

92. The two basic methods for preparing tunnel estimates are: (a) a simulation of actual construction operations in which amounts and types of equipment and materials needed are estimated, crew productivity rates are estimated, the rates of material and labor usage and tunnel advance are set down, and a total estimated cost is computed; and (b) a comparison with similar tunnels in which the unit costs of major construction components, such as excavation, muck hauling, support and lining, and pumping are determined and applied, with or without adjustments for inflation and other factors to the present tunnel, for which the quantities of each component have been computed. Either of these methods may be performed manually or with a computer. The first approach, actual simulation, is more difficult, time-consuming, and accurate. The second approach, the unit cost method, is much easier to use and gives fair results, especially for preliminary estimates or comparison of alternatives.

93. Over the past decade, several computer models have been developed for estimating tunnel costs. The USDOT has provided the primary support for these efforts, and consequently, most of the models were developed for transportation tunnels (railroad, motor vehicle, and rapid transit).

94. Of the four computer models investigated, COSTUN satisfied more completely program objectives for a flexible, easy to use model that can be used by persons lacking an extensive background in tunneling and cost estimating. It has a wide range of applications, including rock, soft ground, and cut-and-cover tunnels, and considers various combinations of conditions and tunnel-driving methods. It also has several well-recognized shortcomings; e.g., aboveground costs are not considered, risk and uncertainty are not treated explicitly, cost equations are based on average costs for tunnels in Chicago in 1969, and method and equipment selection is based on standard practice (circa 1970).

95. Manual estimates and bid preparation will continue as the "tried and true" method for making final estimates. Computer models are

best suited for preliminary estimates, evaluation of alternatives, and checks on manual estimates.

96. The COSTUN model was evaluated using three completed tunnels for which good documentation of geology, construction methods, design, and cost data were available. All three tunnels were driven through rock, and consequently, the model's reliability for estimating costs of soft ground and cut-and-cover tunnels was not verified. For two of the three rock tunnels, COSTUN estimates were within 6 percent of the winning contractor bids and within 7 percent of the actual costs. These figures indicate very good overall accuracy of the model for rock tunnels. However, the accuracy of individual component costs estimated by COSTUN may vary over a wider range. It is difficult to test the validity of these component estimates for two reasons:

- a. Contractor bids are often unbalanced to improve early cash flow. Therefore, construction costs may be overestimated for components used during the early stages of the project and underestimated for components used during latter stages.
- b. Final, as-built costs are usually reported as a lump sum or with only limited itemization, precluding an item by item comparison.

97. For the three tunnels studied, a variation in rock UC strengths of ± 25 percent resulted in estimated cost savings of 6 to 17 percent for a 25 percent reduction in strengths and estimated cost increases of 6 to 20 percent for a 25 percent increase in strengths. The cost impact from a variation in strengths probably depends on the expected strengths more than any other factor. For example, if very low strengths were expected, an increase in strengths might result in a decrease in costs; however, for the tunnels studied, which were built in rock with moderate to high expected strengths, the reverse was true.

98. The estimated cost impact of varying RQD over a ± 33 percent range was a 17 to 24 percent increase in cost for a 33 percent decrease in RQD and about a 10 percent decrease in cost for a 33 percent increase in RQD. Again the cost impact probably depends on the expected RQD values more than any other factor. For example, if the expected RQD values were low, a 33 percent decrease might make tunnel excavation much more

expensive than the impact of a 33 percent reduction in high RQD values for another tunnel.

99. The savings that can be achieved through less conservative lining thickness can be quite significant. For example, 3 in. added to the precast concrete segments specified for the 22-ft-diam Park River Tunnel would have added an estimated \$650,000 to the cost, or about \$72/ft of tunnel. Similar effects were observed in estimates for the other two tunnels, though to a proportionally lesser scale in the 10-ft-diam Nast Tunnel.

100. In slopes and foundations, back analyses can provide knowledge of the actual strengths at failure and yield valuable data for future designs. However, with tunnels there is little historical perspective for altering design methods. Tunnel failures are rare; many have been in service for over 100 years. We know what has been successful in the past, but we do not know how conservative our empirical designs are. Much research has been and is being directed toward this problem. Tunnel experts generally admit that currently available analytical methods outstrip our ability to provide reliable input values for the variables needed for solution. Hopefully, this continued effort will lead to better understanding and more economical designs for support and lining.

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Table 1

Explanation of Typical Geological Parameters
Used to Form Parameter Trees

(TCM)

Item	Explanation
1. Rock Type	Left end node. One parameter tree must be created for each geological unit or rock type to be modeled. Rock type or lithology is used mainly to categorize engineering properties of materials. Main effect on tunneling is rate of drill bit or cutter wear associated with different rock types.
2. Major Defects	First branch of parameter tree. Describes faults (RQD = 0 by definition), clay seams, or for limestone and dolomites, solution cavities.
3. Jointing, RQD	Second branch of parameter tree. Expressed as high (70-100), medium (30-70), or low (0-30) to describe relative condition of rock. Helps in prediction of tunnel support requirements.
4. Foliation	Third branch of tree. Used for metamorphic units. When used for sedimentary rocks, refers to bedding.
5. Gas	Fourth branch of tree. Probabilities assigned to existence or nonexistence of gas. No quantitative estimate is made.
6. Water Inflow	Fifth branch of tree. Probabilities assigned to high and low inflow; no numerical values assigned to inflow rate. May be dependent on jointing and defects to some extent.
7. Compressive Strength	Sixth branch of tree. Probabilities of strength being very high (>32000 psi), high (16000-32000 psi), medium (8000-16000), or low (0-8000) are assigned. Used to assist evaluation of bit and cutter wear, advance rates, blast weights and spacings, and support requirements.

Table 2

Comparison of Computer Models

	COSTUM	TCM	TM	TSC/PMA
Applications:	<ul style="list-style-type: none"> -Tunnels and shafts -Circular, horseshoe, basket-handle, or cut-and-cover box -Finished cross sections from 10 to 40 ft -Rock, soft ground, cut and cover -Excavation by mole, drill and blast, shield w/ripper, mole, or hand except in soft ground 	<ul style="list-style-type: none"> -Tunnels, shafts, adits, caverns -Any shape, size -Rock only -Any excavation method 	<ul style="list-style-type: none"> -Tunnels only -Any shape, size -Rock only -Full-face excavation by mole or drill and blast 	<ul style="list-style-type: none"> -Soft ground only -Transit tunnels and stations -Excavation and lining only
Operation:	<ul style="list-style-type: none"> -Fortran IV, Honeywell GE635, Univac/108 	<ul style="list-style-type: none"> -PL/I, IBM Machine Language I, IBM 370/168 		<ul style="list-style-type: none"> -Lang 2206, data storage on discs
Philosophy:	<ul style="list-style-type: none"> -Preprogrammed standard designs keyed to geological input data for support, lining, dewatering, ventilation, etc. -Advance rate, other calculations based on empirical equations -Computed values may be overridden by user-supplied values for advance rate, lining thickness, stabilization methods, etc. -Uses fixed, user-input geology profile -Most representative of models studied to actual estimating procedures used in industry by owners and engineers -User need not be tunnel expert -Profit, overhead, adjustments for inflation of costs are input by user -Considers any geology -Alternatives can be evaluated -Cost adjustment factors used for labor, materials, equipment, and regional productivity differences 	<ul style="list-style-type: none"> -Probabilistic geology model. User defines parameters to describe each rock unit, with associated probabilities of occurrence -All factors affecting tunnel construction must be input by user. Requires very detailed input. Model has no design capability -Breaks costs down to cycle level of operations -Tunnel simulator models uncertainty in construction operations -Very flexible but requires user with extensive background in tunneling, estimating, and statistical modeling -Contingency costs not considered. Modeling of uncertainty replaces it -Statistical inferences of best case, worst case, and expected cost and time, standard deviation, etc., can be easily made 	<ul style="list-style-type: none"> -User input fixed 2-D or 3-D geology file -Very detailed input for construction method, equipment, crew, etc. -Advance rate calculated by model -Quantities and costs of all construction inputs calculated on per foot basis; user supplies unit cost of materials, labor, and equipment 	<ul style="list-style-type: none"> -Program consists of 2 main data bases -Data Bank 1 describes units of effort required for each construction operation modeled -Data Bank 2 is a unit cost file, based on Washington, D. C., costs for 1976 -Data Banks were based on analysis of 20 tunnels built in United States in last 10 years -Adjustments may be made to Data Banks for inflation, regional differences, etc. -User input includes geometry, geology, location, time, selection of construction method, support and lining method and type, rock removal method, work week, number of bidders and site preparation requirements
Output:	<ul style="list-style-type: none"> -Calculated tunnel and shaft data cost and time summaries 	<ul style="list-style-type: none"> -Progress reports of resources used versus time and progress -Scattergram of cost versus time. Each plotted point represents one tunnel estimate -Optional cost/time summaries for user-selected profiles 	<ul style="list-style-type: none"> -Progress reports and cost reports at user-specified time intervals, including time and cost of completed tunnel 	<ul style="list-style-type: none"> -List of input data, and detailed cost and time summaries for modeled construction operations and direct, indirect, and total project costs -Revisions are planned to take account of legal costs, financing, environmental issues, change orders, insurance, mitigation costs, etc., as well as more comprehensive treatment of tunnel construction operations and conditions
Advantages/ Disadvantages:	<ul style="list-style-type: none"> -Rather simplistic parametric relationships between geology and support design -Based on static technology/costs -Aboveground costs not considered -No treatment of uncertainty -Unsuitable for small projects 	<ul style="list-style-type: none"> -Very detailed input data requirements -Very large storage and computer time requirements -User must have in-depth knowledge of tunneling, estimating, probability, and statistics -Aboveground costs not considered -Validity of subjective probability subject to question -Results difficult to interpret -Only the reasonableness, rather than the accuracy, of solutions can be checked. User must thoroughly verify input data 	<ul style="list-style-type: none"> -Very detailed input requirements -User must have in-depth knowledge of tunnel estimating -Aboveground costs not considered -Limited applications. Soft ground, cut and cover, heading and bench, etc., not considered 	<ul style="list-style-type: none"> -limited application. Considers only soft ground tunnels and stations. Can be used to advantage for comparison of alternatives

Table 3

Nast Tunnel Cost Estimates

Owner: USBUREC
 Built: 1970-1973
 Length: Design length - 15,653 ft; as-built length - 15,740 ft.
 Diameter: Finished - 10 ft
 Shape: Circular and horseshoe
 General geology: Competent granite, porphyry, some crushed zones

Construction Estimates

Estimate No.	Total Cost millions \$	Cost, \$/ft	Comments
Engineer 1	5.103	326	1. Engineer estimate 1 and Contractor bids 1-6 are for the drill and blast excavation schedule
Contractor 1	6.814	435	
Contractor 2	7.238	462	
Contractor 3	8.156	521	2. Engineer estimate 2 and Contractor bids 7-9 are for the mole excavation schedule
Contractor 4	7.983	510	
Contractor 5	8.355	534	
Contractor 6	8.381	535	3. COSTUN estimates are for mole excavation in good quality rock and conventional excavation in poor quality rock
Contractor 7	6.763	432	
Contractor 8	6.568	420	
Contractor 9	9.904	633	4. In all estimates, costs not considered by COSTUN have been subtracted from the manual estimates for sake of comparison
Engineer 2	5.134	328	
COSTUN 1	7.089	453	
COSTUN 2	7.535	481	5. Contractor bids 1 and 7 are from same company, drill and blast and mole schedules, respectively. This company was awarded contract with option of using either excavation method as necessary
COSTUN 3	6.640	424	
COSTUN 4	8.264	528	
COSTUN 5	6.371	407	6. COSTUN estimate 1 represents estimated costs for most likely conditions. COSTUN estimates 2-7 are for possible variations in conditions encountered, or for sensitivity analysis
COSTUN 6	6.562	419	
COSTUN 7	7.573	484	
COSTUN 8	7.089	453	7. As-built costs include costs of relevant change orders
COSTUN 9	7.089	453	
As-built Cost	7.473	477	
COSTUN (As-built)	7.691	491	8. COSTUN as-built estimate includes costs of 87 ft of additional tunneling, which resulted from improper alignment of mole

Table 4

Nast Tunnel COSTUN Estimates

Description	Tunnel Cost, millions \$				Total Constr. Time, days
	Labor	Equipment	Materials	Total	
COSTUN 1 Best estimate of expected conditions	4.738	1.118	1.233	7.089	985
COSTUN 2 Input rock strengths 25% higher than expected strengths	5.094	1.165	1.276	7.535	1084
COSTUN 3 Input rock strengths 25% lower than expected strengths	4.385	1.059	1.196	6.640	883
COSTUN 4 Input RQD 33% lower than expected RQD	5.609	1.279	1.376	8.264	1203
COSTUN 5 Input RQD 33% higher than expected RQD	4.260	0.986	1.125	6.371	865
COSTUN 6 Reduced lining thickness from 18.5" to 12" in segs. 1, 4, 9, 11, 12 and from 14" to 10" in segs. 3, 5, 6, 7, 8, 13 (29 to 33% decrease)	4.546	1.041	0.975	6.562	955
COSTUN 7 Increased lining thickness from 18.5" to 24" in segs. 1, 4, 9, 11, 12 and from 14" to 18" in segs. 3, 5, 6, 7, 8, 10, 13 (29% increase)	4.913	1.168	1.492	7.573	1009
COSTUN 8 Decreased rock temp	4.738	1.118	1.233	7.089	985
COSTUN 9 Increased rock temp	4.738	1.118	1.233	7.089	985
As-built Cost	NA	NA	NA	7.474	1123*
COSTUN (As-built)	5.252	1.129	1.310	7.691	1079

* The number of days required for construction of the tunnel, Granite Adit, Fryingpan Conduit, and other items. No breakdown was available for the tunnel or for the number of crews working simultaneously.

Table 5

Buckskin Mountains Tunnel Estimates

Owner: USBUREC			Diameter: Finished - 22 ft	
Built: 1975-1980			General geology: Complex volcanic rocks	
Length: 35,910 ft			Location: Near Parker, Arizona	
Estimate No.	Total Cost millions \$	Cost, \$/ft	Comments	
Engineer 1	53.991	1504	1. Engineer estimate 1 and contractor bid 1 for 19-ft 6-in.-	
Contractor 1	65.513	1824	diam horseshoe-shaped tunnel, excavated by drill and blast,	
Engineer 2	47.441	1321	with cast-in-place concrete lining	
Contractor 2	71.208	1983	2. Engineer estimate 2 and contractor bid 2 for 20-ft-diam,	
Engineer 3	47.257	1316	circular-moled tunnel with cast-in-place concrete lining	
Contractor 3	44.940	1251	3. Engineer estimate 3 and contractor bids 3-5 for 22-ft-diam,	
Contractor 4	50.915	1418	circular-moled tunnel with precast concrete segmental	
Contractor 5	63.493	1768	lining	
COSTUN 1	51.641	1438	4. Contractor bid 3 awarded the contract	
COSTUN 2	53.841	1499	5. COSTUN estimate 1 for 19-ft 6-in.-diam drill and blast	
COSTUN 3	59.959	1670	tunnel	
COSTUN 4	52.287	1456	6. COSTUN estimate 2 for 20-ft-diam moled tunnel	
COSTUN 5	75.130	2092	7. COSTUN estimates 3-9 for 22-ft-diam moled tunnel with pre-	
COSTUN 6	72.054	2007	cast concrete segmental lining	
COSTUN 7	49.581	1381	8. COSTUN estimates 1-3 for most likely conditions known at	
COSTUN 8	61.373	1709	bid time	
COSTUN 9	62.826	1750	9. COSTUN estimate 4 - RQD increased 15 percent	
As-built Cost	60.0	1671	10. COSTUN estimate 5 - RQD decreased 15 percent	
COSTUN (As-built)	61.474	1712	11. COSTUN estimate 6 - UC strengths increased 25 percent	
			12. COSTUN estimate 7 - UC strengths decreased 25 percent	
			13. COSTUN estimate 8 - lining thickness increased 33 percent	
			14. COSTUN estimate 9 - lining thickness increased 67 percent	
			15. As-built cost does not include pending \$6-million claim	
			16. In all manual estimates, costs not considered by COSTUN	
			have been excluded for sake of comparison	

Table 6

Buckskin Mountains Tunnel

COSTUN Estimates

Estimate No.	Tunnel Cost, millions \$			Total Construction Time, days	Comments
	Labor	Equipment	Materials		
COSTUN 1	28.878	11.006	11.757	2475	Drill and blast excavation - 19-ft 6-in.-diam, horseshoe-shaped tunnel
COSTUN 2	29.875	12.871	11.095	4517	Mole excavation - 20-ft-diam tunnel with cast-in-place lining
COSTUN 3	36.413	13.303	10.243	4095	Base run - 22-ft-diam moled tunnel with precast concrete segmental lining
COSTUN 4	30.937	11.625	9.725	3376	Mole excavation - 22-ft-diam tunnel; RQD increased 15 percent
COSTUN 5	47.033	16.905	11.191	5444	Same to; RQD decreased 15 percent
COSTUN 6	44.224	15.853	11.977	5088	Same to; UC increased 25 percent
COSTUN 7	29.393	11.691	8.497	3106	Same to; UC decreased 25 percent
COSTUN 8	37.149	13.688	10.536	4153	Same to; lining thickness increased 33 percent (from 6-8 in.)
COSTUN 9	37.898	14.085	10.843	4212	Same to; lining thickness increased 67 percent (from 6-10 in.)
COSTUN (As-built)	37.286	13.638	10.550	4204	

Table 7

Park River Tunnel Estimates

Owner: U. S. Army Corps of Engineers

Built: 1978-1980

Length: 9090 ft

Diameter: Finished - 22 ft

General geology: Sedimentary deposits, shale and sandstone

Location: Hartford, Connecticut

Estimate No.	Total Cost, millions \$				Cost \$/ft Tunnel	Comments
	Tunnel	Inlet Shaft	Outlet Shaft	Total Project		
Engineer 1	20.916	0.770	1.100	22.786	2301	1. Engineer estimate 1, COSTUN estimate 10, and contractor bid 1 were for the drill and blast excavation schedule with cast-in-place concrete lining
Contractor 1	24.885	1.800	3.000	29.685	2738	
COSTUN 10	19.476	1.971	1.981	23.428	2143	2. Engineer estimate 2, COSTUN estimate 11, and contractor bid 2 were for the mole excavation schedule with cast-in-place concrete lining
Engineer 2	17.977	0.770	1.100	19.847	1978	
Contractor 2	14.096	3.500	3.000	20.596	1551	3. Engineer estimate 3, contractor bids 3-10, and COSTUN estimates 1-9 were for the mole excavation schedule with precast concrete segmental lining
COSTUN 11	16.785	1.971	1.981	20.737	1847	
Engineer 3	16.123	0.770	1.100	17.993	1774	4. COSTUN estimate 1 represented costs for most likely conditions known at bid time
Contractor 3	11.829	1.500	4.000	17.329	1301	
Contractor 4	14.760	1.100	1.500	17.360	1624	5. COSTUN estimate 2 increased RQD 15 percent
Contractor 5	15.111	1.500	4.000	20.611	1662	
Contractor 6	14.293	3.500	3.000	20.793	1572	6. COSTUN estimate 3 increased RQD 30 percent
Contractor 7	18.270	1.050	3.400	22.720	2010	
Contractor 8	17.689	1.000	2.600	21.289	1946	7. COSTUN estimate 4 decreased RQD 15 percent
Contractor 9	20.351	1.800	3.000	25.151	2239	
Contractor 10	45.310	2.500	2.500	50.310	4985	8. COSTUN estimate 5 decreased RQD 30 percent
COSTUN 1	14.453	1.971	1.981	18.405	1590	
COSTUN 2	13.555	1.971	1.981	17.507	1491	9. COSTUN estimate 6 increased UC strengths 15 percent
COSTUN 3	13.055	1.971	1.981	17.007	1436	
COSTUN 4	15.851	1.971	1.981	19.803	1744	10. COSTUN estimate 7 decreased UC strengths 15 percent
COSTUN 5	19.406	1.971	1.981	23.358	2135	
COSTUN 6	15.543	1.971	1.981	19.495	1710	11. COSTUN estimate 8 increased lining thickness 33 percent
COSTUN 7	13.360	1.971	1.981	17.312	1470	
COSTUN 8	15.103	1.971	1.981	19.055	1661	12. COSTUN estimate 9 increased lining thickness 67 percent
COSTUN 9	15.843	1.971	1.981	19.795	1743	
As-built Cost						13. In all manual estimates, costs not considered by COSTUN have been subtracted for sake of comparison
COSTUN	14.453	1.971	1.981	18.405	1590	
(As-built)						

Table 8

Park River Tunnel COSTUN Estimates

Estimate No.	Project Cost, millions \$		Total	Total Construction		Comments
	Labor	Equipment		Materials	Time, days	
COSTUN 1	11.907	3.559	18.405		611	Base run
COSTUN 2	11.259	3.363	17.507		577	RQD increased 15 percent
COSTUN 3	10.897	3.260	17.007		558	RQD increased 30 percent
COSTUN 4	12.925	3.859	19.803		664	RQD decreased 15 percent
COSTUN 5	15.506	4.635	23.358		797	RQD decreased 30 percent
COSTUN 6	12.637	3.772	19.495		651	UC strength increased 15 percent
COSTUN 7	11.177	3.344	17.312		572	UC strength decreased 15 percent
COSTUN 8	12.240	3.724	19.055		618	Lining thickness increased 33 percent
COSTUN 9	12.617	3.924	19.795		624	Lining thickness increased 67 percent
COSTUN 10	15.387	3.716	23.428		699	Drill and blast option
COSTUN 11	14.442	3.462	20.737		671	Mole option with cast-in-place lining
COSTUN (As-built)	11.907	3.559	18.405		611	

APPENDIX A: USER'S GUIDE FOR PROGRAM COSTUN

Introduction

1. Documentation for the computer program COSTUN for estimating tunnel costs is presented in this appendix and includes the introduction, input data, program execution and printer output, and program listing.

2. COSTUN is available in batch mode on the WES Honeywell GE635 computer. It has been run on a Univac 1108 at the New England Division (NED) Corps Office. The program is too large for the WES Tymesare System. The mainline program COSTUN reads the project title, profit and overhead margins, and beginning project stationing. After these data are read, a series of calls to the various subroutines is initiated. The first subroutine called is INPUT, which reads the general project information, elevations of nodal points, and specific values of all input data for each tunnel segment, tunnel reach, shaft segment, and shaft. The computer performs an extensive check of all input data, and error statements are printed out for mistakes or incompatible data. If errors are encountered that would result in inaccurate solutions, a "Fatal Error" message is printed. Less serious errors are indicated by "Warning" messages. The next subroutine called by the mainline program is SFTSET, which calculates shaft geometry. LENGTH is then called to calculate shaft lengths, hoisting heights, tunnel slopes, and lengths. After these calculations have been made, the input data are printed out by subroutine INOUT under headings "Tunnel Input Data" and "Shaft Input Data." Subsequent subroutines calculate excavated dimensions, spoil quantities, advance rates, pumping heights and quantities, and a host of other factors necessary for a complete estimate. These subroutines and their functions are listed and described by comment cards in the program listing and in the documentation report.

Input Data

3. Input data must be entered on the file cards, with all data right-justified within formats. The job control cards are placed at the front of the deck and then followed by:

- Item 1. Title cards. All 10 must be included, even if blank. Any alphanumeric data may be entered in columns 1-64.
- Item 2. Printout options (one card). Enter code 0 or leave blank to print all input data, 1 in column 1 to suppress nodal points, 1 in column 2 to suppress tunnel input data, 1 in column 3 to suppress shaft input data, 1 in column 4 to suppress calculated tunnel data, 1 in column 5 to suppress calculated shaft data, 1 in column 6 to suppress tunnel segment and reach costs, 1 in column 7 to suppress shaft segment and shaft costs, 1 in column 8 to suppress tunnel reach cost summary, and 1 in column 9 to suppress shaft cost summary.
- Item 3. Profit and overhead margins and beginning of project stationing (one card). Columns 1-10 contain profit margin in percent, columns 11-20 overhead margin in percent, and columns 21-30 beginning project stationing, any positive or negative number between $\pm 10,000$. As an example, enter 4059.6; not 40 + 59.6.
- Item 4. Nodal point elevations. Use one card per nodal point. Place nodal point number in columns 2-5. Place nodal point elevations in columns 11-20. Nodal points are used to designate the ground surface elevation at each shaft or portal and the ends of shaft and tunnel segments. Tunnel segment elevations should be referenced to center-line elevations and to ground surface for cut and cover.
- Item 5. Data separator (one card). Enter 999999 in columns 1-6.
- Item 6. Tunnel segment data. Include one card per segment. Data for soft ground and cut-and-cover segments are continued on a second card. Columns 1-4 contain the segment number; the sequence of cards must correspond to the sequence of segments within a reach. The left nodal point number is placed in columns 5-8, right nodal point number in columns 9-12, and the horizontal length of the segment, in feet, in columns 13-20. Columns 21-24 contain the tunnel reach number. The UC strength of intact rock, in pounds per square inch (psi), is entered in columns 25-31 for rock segments only. RQD is entered in columns 32-36 in percent, with any positive number between 25 and 100, for rock or cut-and-cover segments. For cut-and-cover segments, RQD refers to material below

sound rock elevation (see columns 55-60 on continuation card). Excavation method is coded in column 39. Enter code 1 for conventional (drill and blast), 2 for moled rock, 3 for moled soft ground, 4 for soft ground hand excavation, 5 for soft ground ripper excavation, 6 for cut and cover with vertical sidewalls, and 7 for cut and cover with sloping sidewalls. The uniform advance rate is entered in feet per day in columns 40-44. If left blank, COSTUN will calculate the value.

The data base used to form the program's advance rate equations is rather small for moled rock tunnels and moled shafts. Therefore, the user should examine advance rates calculated by COSTUN for these methods to see if they appear reasonable. The uniform advance rate, whether calculated by COSTUN or input by the user, is the advance rate that would be achieved if the segment were sufficiently long to permit work crews and equipment to reach peak efficiency. However, much time is lost during project start-up, when switching to new headings, or when changing excavation methods. Thus, the average advance rate is always less than the computed uniform advance rate. The average advance rate, on which costs are based, is computed internally by COSTUN by making adjustments to the uniform advance rate, as described previously. Water inflow is coded in gallons per minute in columns 45-51 and refers to inflow at the working face. Lining type is entered in column 54 with code 0 for unlined segment, 1 for cast-in-place concrete lining, 2 for shotcrete lining, 3 for precast concrete cut-and-cover box, and 4 for precast concrete segmental lining.

4. The option for precast concrete segmental lining was not included in the original COSTUN program. This subroutine was developed by NED personnel, based on limited experience, and should be used with caution. Adjustments to the cost base for this option are anticipated as experience is gained. This option requires that a lining thickness be input in columns 55-60 and the specified shape be circular with a watertight lining and mole excavation.

5. The user must ensure that the data discussed previously for precast segments are input, or the output will be erroneous. An error message is not printed out for erroneous input on the precast segment

option. Acceptable conditions for other specified lining types, such as the unlined segment (code 0), are: (a) in rock segments if watertight lining is not required (columns 73-75), and (b) in soft ground segments provided the support type on the continuation card (columns 52-54) is code 1, 2, or 3 for cast iron segments, precast concrete segments, or steel segments, respectively. However, an unlined segment is unacceptable in cut-and-cover segments. Lining code 1 or 2 must be used in conjunction with support code 4 in soft ground segments; code 0 or 2 is unacceptable in cut-and-cover segments; and code 3 is unacceptable in rock or soft ground segments. Lining thickness is input in columns 55-60. If left blank, COSTUN will calculate the thickness of cast-in-place concrete lining (code 1 in column 54) or shotcrete (code 2 in column 54). For unlined segments, it will calculate the backplate thickness of soft ground segmental supports (code 1, 2, or 3 in column 54 of continuation card). For precast concrete segmental lining (code 4 in column 54), the thickness must be input. If a thickness is input for code 3 (cut-and-cover precast concrete box), it will be ignored. Rock or soil temperature is coded in degrees Fahrenheit in columns 61-64 for rock and soft ground segments. In column 66, the user should enter code 0 if formwork costs for cast-in-place concrete lining are to be computed and code 1 if formwork costs are to be eliminated. Code 1 should be used when the concrete is cast behind the steel liner plate that serves as the form. Groundwater elevation is input in columns 67-72. The average groundwater elevation within the segment should be used. Column 75 is used to designate whether a watertight lining is required. In this column, the user should enter code 0 for a drained lining or drained soft ground support, or for groundwater elevation below the segment invert elevation, and code 1 for watertight lining or soft ground tunnel support. A cut-and-cover lining is automatically designated watertight. Tunnel type is coded in column 80 with 1 for rock, 2 for soil, and 3 for cut and cover.

- Item 7. Tunnel segment continuation card. Include one card for each soft ground or cut-and-cover segment immediately after the main segment card to which it applies. Enter data as follows:

Columns 5-8 - Left-ground surface nodal point number.

Columns 9-12 - Right-ground surface nodal point number.

Columns 13-20 - Effective grain size D_{10} , in millimetres.

Columns 21-24 - Enter the undrained angle of internal friction ϕ in degrees.

Columns 25-31 - Enter undrained soil cohesion, in pounds per square foot (psf).

Columns 32-36 - Enter saturated unit weight of soil, in pounds per cubic foot (pcf). If no value is input, COSTUN uses the default value of 120 pcf.

Columns 37-39 - Enter dewatering option; use code 0 if dewatering is not permitted. Code 1 must be used for sloping-sided open cuts if groundwater elevation is above the bottom of the trench and the impervious layer is below groundwater elevation.

Columns 40-44 - Enter average elevation of groundwater within segment.

Columns 45-51 (optional input) - Enter soil permeability, in centimetres per second (cm/sec), for the strata in which dewatering or face stabilization will occur. If no value is input, COSTUN will compute from the empirical relationship

$$K = CD_{10}^2$$

where C is an empirical factor and D_{10} is the effective grain size in millimetres.

Column 54 (support type) - Enter code 0 for sloping-sided open cuts, 1 for soft ground supported by cast iron segments, 2 for soft ground supported by pre-cast concrete segments, 3 for soft ground supported by steel segments, 4 for soft ground supported by steel ribs and lagging (used with lining codes 1 or 2 in column 54 of main segment card), 5 for vertical-sided open cuts supported by soldier piles and lagging, and 6 for vertical-sided open cuts supported by slurry walls.

Columns 55-60 - Required only for cut and cover. Enter the average sound rock elevation within the segment, below which RQD is greater than or equal to 50.

Column 64 - Required only for cut and cover. Enter the method of bracing open cuts with code 0 for sloping-sided open cuts, 1 for exclusive use of

struts, 2 for exclusive use of tieback anchors, and 3 for struts above the box roof and tieback anchors below the box roof.

Column 66 - Required only for cut and cover. Enter the decking requirement option with codes 0 and 1 to be used for no decking, respectively.

Columns 67-72 (optional input) - Enter stability number. For vertical open cuts, enter the value above sound rock including benefits of dewatering. For soft ground tunnels, enter the value at the face, after stabilization. Leave blank for sloping-sided open cuts or when it is desired to let COSTUN compute the value. For soft ground segments, the stability number input must be between 0 and 9 if the angle of internal friction is less than 29 deg and must be between 0 and 7 if the angle of internal friction is greater than or equal to 29 deg.

Column 74 - Required only for soft ground. Enter the soft ground face stabilization method with code 0 if no stabilization method is to be used, or if 1 or 2 is entered in column 75, 1 for compressed air, 2 for dewatering, and 3 for ground injections.

Column 75 - Required only for soft ground. Enter code 1 to allow COSTUN to select method for face stabilization and check for increased stability (reduce stabilization number) based solely on input parameters and internal calculations. Use code 2 to have COSTUN select a stabilization method only if the tunnel otherwise cannot be excavated, 3 to have COSTUN use the preferred method entered in column 74 above only if the tunnel otherwise could not be excavated, and 4 if the method entered in column 74 is to be used regardless of face stability. If code 1 or 2 is entered in column 75, column 74 must be blank or contain a zero; if code 3 is entered in column 75, a method must be specified in column 74. Columns 67-72 must be blank if code 1, 2, or 3 is entered in column 75. A stability number or stabilization method must be entered in columns 67-72 if code 4 is entered in column 75.

Columns 76-80 - Required only for soft ground. Enter the air pressure, in psi, between 0 and 50 to be used for face stabilization. Zero must be entered if column 74 does not contain code 1 and if column 75 does not contain code 3 or 4. If compressed air is specified (code 1) or selected in column 74, then the air pressure must be greater than zero in columns 76-80.

Item 8. Data separator (one card). Enter 999999 in columns 1-6.

Item 9. Tunnel reach data. Include one card per reach.

Columns 1-4 - Enter the reach number.

Columns 5-8 - Enter the exit shaft number.

Columns 9-14 - Required only for rock or soft ground.
Enter the characteristic finished dimension, in feet,
with any number from 10 to 40.

Column 17 - Required only for rock or soft ground.
Enter the tunnel shape with code 1 for circular, 2
for horseshoe, and 3 for baskethandle.

Column 20 - Required only for rock or soft ground.
Enter the muck transport method with code 1 for
truck, 2 for conveyor, 3 for train, and 4 for con-
veyor in compressed air and truck in free air.

Columns 21-25 (optional input) - Enter the number of
work hours per day. If no value is input, the de-
fault value of 24 hr is used.

Columns 26-29 (optional input) - Enter the number of
work days per week. Default value is 6.

Columns 30-32 - Required only for cut and cover. Enter
the number of contiguous box units in a single-level
cut-and-cover box.

Columns 33-37 - Required only for cut and cover. En-
ter finished box width, in feet. For a single-level
box, width equals clear span times number of units.
For a double-level box, width equals two times the
single level width. Any positive number between 10
and 40 may be input.

Columns 38-42 - Required only for cut and cover. En-
ter finished box height, in feet. For single-level
box, height equals clear height of one unit; height
of double-level box equals two times clear height of
one unit. Any positive number between 10 and 20 is
permissible for a single-level box and between 10
and 40 for a double-level box.

Columns 43-45 - Required only for cut and cover. En-
ter the select box option with codes 0 and 1 to be
used for single-level and double-level box, respec-
tively.

Item 10. Data separator (one card). Enter 999999 in columns 1-6.

Item 11. Shaft segment data. Include one card per segment.
Data for soft ground and cut-and-cover segments are
continued on a second card. For rock shaft segments,
dummy shafts, or portals, the continuation card must
be omitted.

Columns 1-4 - Shaft number.

Columns 5-8 - Segment number. Enter any positive integer from 1 to 999. Within any shaft, the segment numbers must be exclusive, but in different shafts, the numbers may be duplicated. Shaft segment numbers need not be in sequence, but sequential arrangement of cards must be from top to bottom of shafts.

Columns 9-12 - Upper nodal point number. Enter the number of the nodal point at the top of the segment.

Columns 13-16 - Lower nodal point number. Enter the number of the nodal point at the bottom of the segment; if a portal, this number should be identical with the upper nodal point number.

Columns 25-32 - Required only for rock. Enter intact, UC rock strength, in psf or in psi, with any positive number. Leave blank when the shaft is a portal.

Columns 33-36 - Required only for rock. Enter RQD in percent, with any positive number from 25 to 100. Leave columns blank when the shaft is a portal.

Columns 37-39 - Required only for rock or soft ground. Enter the excavation method with code 1 for conventional rock excavation, 2 for moled rock excavation, 3 for moled soft ground excavation, or 4 for hand excavation in soft ground. Leave blank when the shaft is a portal or a dummy.*

Columns 40-45 (optional input) - Enter uniform advance rate with any positive number, in feet per working day; if blank or contains a zero, COSTUN computes the advance rate. Leave blank when the shaft is a portal or a dummy.

Columns 46-48 - Rock only. For water inflow, enter code 1 for waterbearing formations; leave blank when the shaft is a portal or for dry formations. Control of inflow in shafts is assumed to be invariant. If inflow occurs, grouting around the perimeter of the shafts is the assumed control method. Costs are based on grout holes drilled on 5-ft centers around the perimeter of the shaft for the entire thickness of the waterbearing formation.

Columns 49-51 - Lining type. For unlined segment, portal, or dummy, enter code 0 or leave blank; for cast-in-place concrete lining, code 1; for shotcrete

* Note: A dummy shaft is an imaginary shaft used for internal bookkeeping purposes only to separate segments constructed by different excavation methods. No costs are calculated for a dummy shaft.

lining, code 2; and for precast cut-and-cover lining, code 3. An unlined segment is acceptable in rock segments provided a watertight lining (columns 66-68) is not required; in soft ground segments provided the support type (columns 49-51 on continuation card) is code 1, 2, or 3; and in cut-and-cover segments provided the shaft is a portal or a dummy. When lining code 1 or 2 is used in conjunction with support code 4 in soft ground segments, code 1 or 2 is unacceptable in cut-and-cover segments, and code 3 is unacceptable for rock or soft ground segments.

Columns 52-57 (optional input) - For lining thickness, enter any positive number, in inches; leave blank when shaft is a portal or a dummy. A thickness may be input for code 0, 1, or 2 above; for code 0, the value input refers to the backplate thickness of segmented soft ground shaft supports (code 1, 2, or 3 in columns 49-51 of continuation card).

Columns 58-59 - For formwork to be used in conjunction with cast-in-place concrete linings in soft ground or rock segments, enter code 0 or leave blank if formwork costs are to be computed and code 1 if formwork costs are to be eliminated. Code 1 should be used if the concrete is to be cast behind a steel liner that serves as the form. Note that the cost of the steel liner is not computed by COSTUN.

Columns 60-65 - Groundwater elevation. Leave blank for a portal or a dummy shaft. Enter any number representing the average groundwater elevation for the entire shaft.

Columns 66-68 - Watertight lining or soft ground shaft support. For an unlined shaft segment, for a drained lining or drained soft ground support, for a groundwater table below the segment, or for a portal or dummy shaft, enter code 0 or leave blank; for a watertight lining or soft ground shaft support, enter code 1. Note that a cut-and-cover lining is automatically designed as watertight.

Columns 69-73 - Shaft type. For rock, dummy, or portal, enter code 1; for soft ground, code 2; and for cut and cover, code 3.

Item 12. Shaft segment continuation card. Include this card only if the segment is soft ground or cut and cover (code 2 or 3 in columns 69-73 of main card). This card must be placed immediately behind the main card to which it applies.

Columns 17-24 - Effective grain size D_{10} , in millimetres.

Columns 25-32 - For undrained soil cohesion, in psf, enter zero or blank or any positive number. Usually this value is zero for sands and gravels, but it cannot be zero if columns 37-39 below are also zero or blank.

Columns 33-36 (optional input) - For unit weight of soil, in pcf, enter zero or blank or any positive number up to 200. If no value is input, COSTUN will assume 120.

Columns 37-39 - Undrained angle of internal friction, in degrees.

Columns 40-45 - For elevation of impervious layer, enter any number representing the elevation for the segment. Not required for soft ground segments if dewatering is not permitted or if the ground is not capable of being dewatered ($D_{10} \leq 0.08$ mm or PERM ≤ 0.0006 cm/sec); not required for cut-and-cover segments.

Columns 46-48 - Dewatering permitted. For cut-and-cover segments or if lowering of the groundwater table by pumping is not permitted, enter code 0 or leave blank; if lowering of the groundwater table is permitted, enter code 1.

Columns 49-51 - Support type. For soft ground supported by cast iron segments, enter code 1; for soft ground supported by precast concrete segments, code 2; for soft ground supported by steel segments, code 3; for soft ground supported by steel ribs and lagging (used with lining code 1 or 2 in columns 49-51 on main segment card), code 4; and for cut-and-cover construction, code 5.

Columns 52-59 (optional input) - For soil permeability, in cm/sec, enter the permeability at the level in which dewatering or face stabilization will occur; omit for cut-and-cover segments. If no value is input, COSTUN will compute if needed.

Columns 60-65 (optional input) - Stability number. For soft ground segments, enter the value at the face including the effect of any stabilization methods; for cut-and-cover segments, leave blank. If no value is to be input or if it is desired to let COSTUN compute it, enter code 0 or leave blank. Otherwise, input any number from 0 to 9 if $\text{PHI} < 29$ or any number from 0 to 7 if $\text{PHI} \geq 29$.

Columns 66-67 - Required only for soft ground. Stabilization method; in conjunction with column 68 below, the soft ground face stabilization method either preferred or desired to be used; for required use of no method or for code 1 or 2 in column 68, enter code 0 or leave blank; for stabilization by compressed air, code 1; for stabilization by dewatering, code 2; and for stabilization by ground injections, code 3.

Column 68 - Required only for soft ground. To allow COSTUN to select a face stabilization method and check for a significant reduction in the stability number based solely on input parameters, enter code 1; to have COSTUN select a stabilization method only if the tunnel could not otherwise be excavated, code 2; to have COSTUN use the preferred stabilization method (columns 66-67 above) only if the shaft could not otherwise be excavated, code 3; to have COSTUN use the given stabilization method regardless of the face stability, code 4. For code 1 or 2, a face stabilization method must not be specified in columns 66 and 67; for code 3, a method must be specified in columns 66 and 67; for codes 1, 2, and 3, a stability number must not be input in columns 60-65; and for code 4, either a stability number or a stabilization method (both are also acceptable) must be input (blank or zero in columns 66 and 67 indicates no stabilization method is to be used).

Columns 69-73 - Required only for soft ground. For the air pressure to be used for face stabilization, in psi, input any positive number from 0 to 50. If a stability number is input and the stabilization method selected is compressed air, a number greater than zero must be input; a value other than 0 must not be specified if columns 66-67 do not contain code 1 and if column 68 does not contain code 3 or 4.

Item 13. Data separator (one card). Enter 999999 in columns 1-6.

Item 14. Shaft data. Include one card per shaft.

Columns 1-4 - Shaft number.

Columns 5-10 - Shaft size. Enter the characteristic finished dimension, in feet, with any number from 10 to 40. Leave blank when the shaft is a portal or a dummy.

Columns 11-13 - Shaft shape. For a dummy or portal, enter code 0 or leave blank; for a circular shape, code 1; and for a square shape, code 2.

Columns 14-21 - Distance to disposal. Enter distance to user-selected disposal site, in miles.

Columns 22-28 - Cost of the disposal site, in dollars per acre.

Columns 29-32 - For aboveground air temperature, in degrees Fahrenheit, any positive or negative number is entered but can be omitted if all reaches associated with the shaft are cut and cover.

Columns 33-38 - Labor cost index. Calculate by dividing the cost of labor for period of consideration by costs of labor in Chicago in 1969. This value was \$35.17 in Chicago in 1969 and consisted of hourly wages and fringes for heavy construction, one each; common labor plus skilled iron workers plus hoisting engineers plus tractor operators plus air compressor operator plus truck driver. This mix is representative of labor employed in tunnel construction. Rates are published monthly by Engineering News Record (ENR) for 20 cities and annually for an additional 25 cities. In addition, information on labor rates may be obtained by contacting the U. S. Bureau of Labor Statistics, union offices, or local employment offices.

Columns 39-44 - Equipment cost index. Based on ENR quarterly report of "Equipment List Price Trends, All Types of Equipment." Equipment Cost Index is calculated by dividing the index value for the period of consideration by the index value in 1969, which was 110.4 on a base of 100 for 1967.

Columns 45-50 - Material cost index. Calculate by dividing the ENR Construction Cost Index, material prices for location of the project for the period of project construction, by the Chicago index for 1969. The unit of materials to use consists of 22.5 cwt bulk cement, carload lots (prior to 1972 used 6 bbls), 1 Mfbm of pine or fir 2x4's, and 25 cwt standard structural steel shapes, W8x31, base price, FOB warehouse. The 1969 Chicago cost of these mtl's was \$402.50.

Columns 51-56 - Regional cost factor. Used to assess construction cost differences in various regions of the United States. Enter 0.9 for Chicago, 1.2 for San Francisco, 2.0 for New York City, 0.8 for all other areas, or any other number the user deems appropriate.

Columns 57-61 (optional input) - For work hours per day, enter any positive number from 0 to 24. If no value is input, 24 will be assumed.

Columns 62-65 (optional input) - For work days per week, enter any positive number from 0 to 7. If no value is input, 6 will be assumed.

Item 15. Data separator (one card). Enter 999999 in columns 1-6.

Item 16. End of system (one card). Enter end of system in columns 1-13.

6. At this point, input decks for additional tunnel-shaft systems may be prepared. The additional decks should start with the title cards and end with the end of system card above. The additional system data decks may be stacked for a single computer run. Final job control cards are placed behind the last end of system card.

Fatal errors

7. Data inputs that would cause material inaccuracies in the problem solution and that can be identified by internal checks in sub-routines INPUT, SFTSET, and LENCETH are programmed to halt execution of the computations. Such inputs, are, therefore, called "fatal" errors. The following tabulation is a complete listing of all fatal errors checked in INPUT, SFTSET, and LENCETH. The Format Statement Number is the number of the statement in the program listing that will be printed out as a result of the error. All are checked in INPUT except as noted in paragraph 7.

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
No separator card after nodal point card	1500	1500
Duplicate nodal point number	1013	1013
Nodal point < 1 or > NPMAX*		
NPMAX = max. no. of nodal points	1001	1001
Number of segments > NTSMAX* or NSSMAX*		
NTSMAX = max. no. of tunnel segments allowed		
NSSMAX = max. no. of shaft segments allowed	1016	1017
No separator card after tunnel segment data or tunnel type coded incorrectly	1501/2000	--

* See the program listing (paragraph 16) for present dimensions of these variables.

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
Duplicate reach or shaft number	1022	1023
Segment card out of sequence	1015	1115
Nodal point card omitted	1031	1131
Excavation method coded incorrectly	1030	1029
Excavation method does not match tunnel or shaft type	2005	2210
Thickness specified; no lining	1045	1046
Lining type coded incorrectly	1043	1048
Lining type does not match tunnel or shaft type	2010	2220
Input advance rate less than zero	1065	1075
Watertight lining requirement coded incorrectly	2015	2225
No lining or support specified for watertight tunnel or shaft	2020	2230
RQD < 25 in rock tunnel or shaft	2030	2212
RQD < 0 or > 100	1062	1072
Surface nodal point out of sequence	2040	--
Surface nodal point card omitted	2045	--
Surface nodal point elevation below tunnel	2050	--
Effective grain size not specified	2055	2245
Soil strength not specified	2060	2250
Friction angle > 100 deg	2063	2253
Unit weight of soil > 200 pcf	2064	2254
Dewatering requirement coded incorrectly	2065	2255
Impervious layer above ground surface	2072	--
Impervious layer at ground surface, soil not clay	2073	--
Impervious layer above base of shaft segment	--	2262
Support type coded incorrectly	2075	2265
Support type does not match tunnel or shaft type	2080	2270
Lining type does not match support type	2085	2275
Rock elevation above ground surface	2092	--
Bracing code < 0 or > 3	2095	--
Bracing code for vertical cut ≤ 0	2100	--
Decking coded incorrectly	2105	--

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
Stability number too high; excavation impossible	2115	2285
Stabilization method coded incorrectly	2120	2290
Stabilization use coded incorrectly	2125	2295
Air pressure not specified for compressed air stabilization with input stability number	2130	2300
Stability number specified; incorrect stabilization use code	2135	2305
Air pressure specified; compressed air stabilization not specified	2137	2307
Stabilization use code does not match method	2140	2310
Unacceptable stabilization method input	2147	2320
No separator card after reach data	1502	--
Reach number < 1 or > NTRMAX	1021	--
Size indicates cut-and-cover; shape code is not zero	2150	--
Shape indicates cut and cover; size in wrong column	2151	--
Duplicate reach or shaft data cards	1026	1027
Muck transport method coded incorrectly	1041	--
Shape coded incorrectly	1042	2325
Shape indicates cut and cover; muck transport method specified	2152	--
No muck transport method specified	2153	--
Work hours per day < 0 or > 24	2155	2335
Work days per week < 4 or > 7	2160	2340
Box dimension(s) not input	2165	--
Number of box units not specified for cut and cover	2175	--
Noncircular shape for mole excavation	1040	2355
Compressed air required; truck muck transport specified	2195	--
Cast iron support specified for noncircular shape	2200	2350
Tunnel is not cut and cover; no shape specified	2201	--
Shape specified is not for cut and cover	2202	--
RQD of sound rock < 25 for cut and cover	2204	--
Sloping cut through pervious ground below GWT; dewatering must be allowed	2205	--

<u>Description</u>	<u>Format Statement No.</u>	
	<u>Tunnels</u>	<u>Shafts</u>
Segment in nonexistent reach or shaft	1200	1201
Reach or shaft number not referred to	1203	1204
Reach ends at nonexistent shaft	1202	--
Shaft number < 1 or > NSMAX	--	1034
Groundwater elevation within shaft segment	--	2240
Shaft inflow coded incorrectly	--	1047
Shape indicates a dummy shaft, size given	--	2330
Size indicates a dummy shaft, shape code not zero or blank	--	2332
Square shaft in rock	--	2345
Missing separator card after shaft segment data, or shaft type coded incorrectly		1503/2207
No separator card after shaft data	--	1504
No cut-and-cover segments in a cut-and-cover shaft (SFTSET)		1000
No cut-and-cover segment adjacent to dummy shaft (LENGTH)	--	2000

8. Fatal errors may also be detected after some preliminary processing in subroutines CALCS, AIRPRS and STABIL that are identified in the program listing. In this case, the calculated tunnel data and calculated shaft data will be printed out (unless suppressed), and then the program execution will be halted. Fatal errors in this category are listed below.

<u>Description</u>	<u>Format Statement No.</u>		
	<u>Tunnels</u>	<u>Shafts</u>	<u>Subroutine</u>
Stability number too high after stabilization; excavation impossible	2000	3000	STABIL
Stabilization is required but input method not acceptable	2030	3030	STABIL
Stabilization is required but input method not effective	2035	3035	STABIL

<u>Description</u>	<u>Format Statement No.</u>		
	<u>Tunnels</u>	<u>Shafts</u>	<u>Subroutine</u>
Stabilization is required but input specifies no method must be used	2050	3050	STABIL
Excavation impossible by using air pressure < 50 psi	2000	3000	AIRPRS
Haul slope too steep for a train	1020	--	CALCS
Tunnel too small for a truck	1021	--	CALCS
Slope too steep for muck transport methods	1023	--	CALCS
Truck muck transport in compressed air tunnel	1025	--	CALCS

Nonfatal errors

9. Data inputs that are beyond the range for which the cost relationships are believed to apply with accuracy are nonfatal errors. These errors will not halt execution of the program, but a warning will be printed out to call attention to their existence. Included in the category of nonfatal errors are various reminders and warnings as to the final use of certain input data.

<u>Description</u>	<u>Format Statement No.</u>		
	<u>Tunnels</u>	<u>Shafts</u>	<u>Subroutine</u>
Rock strength < 500 psi	1060	1070	INPUT
Cut-and-cover segments are watertight	2017	2227	INPUT
Groundwater elevation is zero or blank, used zero	2025	2235	INPUT
RQD > 25 for soft ground tunnel	2035	2215	INPUT
Coefficient of permeability > 10 cm/sec	2061	2251	INPUT
Friction angle > 45 deg	2062	2251	INPUT
Impervious layer elevation is zero or blank, used zero	2070	2260	INPUT
Rock elevation is zero or blank, used zero	2090	--	INPUT
Cut-and-cover box deeper than 100 ft	2094	--	INPUT
Stabilization method is not acceptable	2145	2315	INPUT
Size < 10 or > 40 ft	1064	1074	INPUT

<u>Description</u>	<u>Format Statement No.</u>		<u>Subroutine</u>
	<u>Tunnels</u>	<u>Shafts</u>	
Box width exceeds 40 ft	2170	--	INPUT
Box height > 20 ft for single-level box	2180	--	INPUT
Box height > 40 ft for double-level box	2185	--	INPUT
Impervious layer above tunnel, $D_{10} > 0.005$	2190	--	INPUT
RQD of sound rock is 25-50 for cut and cover	2203	--	INPUT
No excavation method specified; dummy shaft assumed	--	2208	INPUT
Dummy shaft, cost=0	--	2327	INPUT
Shaft depth > 3000 ft	--	1071	LENGTH
Reach length > 20 miles	1061	--	LENGTH
Input thickness less than standard design, input ignored	1010	1011	SIZEST/SIZES
Input thickness appear to be inadequate for water pressure	2710	2711	SIZEST/SIZES
Lining thickness was input for cut-and-cover box	3500	--	SIZEST/SIZES
Groundwater below segment; input inflow ignored	3600	3605	SIZEST/SIZES
Stabilization method not effective; no method used	2010	3010	STABIL
Input stabilization method not required	2015	3015	STABIL
Input stabilization method not acceptable nor required	2020	3020	STABIL
Stabilization method not effective; method used anyway	2025	3025	STABIL
Hand excavation used rather than input method	2040	3040	STABIL
Conveyor/truck transport used rather than input method	1030	--	CALCS

10. Several of the above messages are caused by elevations that are not associated with nodal points. INPUT makes extensive checks for missing input data. Unfortunately, the computer cannot distinguish between a zero and a blank data field. Therefore, COSTUN cannot be certain that the user meant elevation 0 or just forgot to input a number. These messages can be avoided by specifying an elevation close to zero, like 0.1 or 0.01, if elevation 0 is indeed desired.

Program Execution and Printout

Program execution

11. COSTUN is executed in core. During operation it neither refers to information stored on another tape nor generates another data tape. Therefore, no special operating instructions are necessary.

12. The program stores most data in one of five arrays (A, B, CNP, SHAFT, and TRDATA). These five arrays are stored in one main array called ARRAY. This procedure allows the user to alter the storage requirements of COSTUN. The storage requirements are a function of the allowable number of tunnel and shaft segments, tunnel reaches, and shafts. COSTUN as written provided for NTSMAX (maximum number of tunnel segments) = 300, NSSMAX (maximum number of shaft segments) = 300, NSMAX (maximum number of shafts) = 100, and NTRMAX (maximum number of reaches) = 200. The version presented in the program listing allows NTSMAX = 20, NSSMAX = 10, NSMAX = 10, and NTRMAX = 20.

13. The storage requirements can be changed by changing any or all four of these key variables in the main program. If the change is made after the initial compilation, then only the main program needs to be recompiled. If these variables are made larger, the dimension of ARRAY (first execute card in MAINLINE) must be increased. If these variables are made smaller, the dimension of ARRAY need not be changed, but failure to do so will result in paying for more computer storage than necessary. The minimum dimension of ARRAY is given by

$$\text{ARRAY} = 74 \times \text{NTSMAX} + 46 \times \text{NSSMAX} + 23 \times \text{NSMAX} + 23 \times \text{NTRMAX}$$

14. For the values originally provided for these four key variables, the minimum dimension of ARRAY was 42,900. If the dimension of ARRAY is changed to less than the minimum required dimension, a message will be printed and the computer run will terminate. Whenever the dimension of ARRAY is changed, the value of MM (fifth execute card in MAINLINE) must also be changed to that of the new dimension of ARRAY. The present dimension of ARRAY is 2630. This size allows most tunnels to be estimated without problems and saves some storage costs.

Printout

15. The printout consists of the tunnel and shaft title and all other input data, unless the suppress option, described previously in paragraph 3, is used to suppress one or more items of input data. After the selected input is printed out, the program prints out calculated tunnel data, consisting of length, slope, excavated dimensions and quantities, advance rates, lining thickness, pump rates and heads, and construction time. Position of the airlock, if used, stabilization method used, unit weights, permeability, concrete volumes, and backfill volumes are listed where appropriate for each tunnel segment within each reach. The same categories of calculated data are printed out for each shaft under the heading, "Calculated Shaft Data." Next, tunnel costs are listed by reach and segment number under column headings for excavation setup, excavation, muck loading, muck hauling, muck hoisting, muck disposal, supports, lining, lining formwork, grouting, pumping, and air conditioning, and these unit costs are tallied to obtain the segment cost per foot and total segment costs, which are printed. This process is repeated for each segment. Then a summary of reach costs is printed, applying the cost adjustment factors to labor costs, equipment costs, and material costs to obtain total reach costs. Such a printout is also prepared for each reach and for each shaft. A "Tunnel Reach Cost Summary" is printed next, applying the Regional Cost Factor to the total, followed by a similar "Shaft Cost Summary." The final output block reprints the project title and the profit and overhead margins, and then lists the project summary costs for labor, equipment, and materials, and the total costs.

Program Listing

16. A listing of program COSTUN is given below.

```

C MAINLINE PROGRAM ----- COSTUN ----- 000020 0000
C ***** 000030 0000
C DIMENSION ARRAY (2630) 000040 0000
C COMMON /BASIC/ NSS,NTS
C COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE 000060 0000
C COMMON /F/ IERROR,ISTOP 000070 0000
C COMMON /G/ TUNLC,TUNEC,TUNMC,TUNTC 000075 0000
C ----- 000080 0000
C WHENEVER THE DIMENSION OF 'ARRAY' IS CHANGED, THE VALUE OF MM 000090 0000
C BELOW MUST ALSO BE CHANGED TO THAT OF THE NEW DIMENSION OF 'ARRAY' 000100 0000
C MM=2630 000110 0000
C ----- 000120 0000
C NSMAX=10 000130 0000
C NSSMAX=10 000140 0000
C NTRMAX=20 000150 0000
C NTSMAX=20 000160 0000
C NPMAX=NSSMAX+2*NTSMAX 000170 0000
C J1 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'A' ARRAY 000180 0000
C J2 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'B' ARRAY 000190 0000
C J3 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'CNP' ARRAY 000200 0000
C J4 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'SHAFT' ARRAY 000210 0000
C J5 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN 'TRDATA' ARRAY 000220 0000
C J6 = STORAGE LOCATION IN 'ARRAY' OF FIRST ITEM IN CUMSL 000230 0000
C J1 = 1 000240 0000
C THE NUMERICAL COEFFICIENTS ON THE NEXT 5 LINES REPRESENT THE 000250 0000
C NUMBER OF ITEMS STORED IN THE A, B, CNP, SHAFT, AND TRDATA 000260 0000
C ARRAYS, RESPECTIVELY 000270 0000
C J2 = J1 + 68*NTSMAX 000280 0000
C J3 = J2 + 43*NSSMAX 000290 0000
C J4 = J3 + 2*NPMAX 000300 0000
C J5 = J4 + 23*NSMAX 000310 0000
C J6 = J5 + 23*NTRMAX 000320 0000
C LI=5 000330 0000
C LO=6 000340 0000
C ----- 000350 0000
C THE MINIMUM REQUIRED SIZE OF 'ARRAY' IS J6+ NPMAX-1 000360 0000
C OR 74*NTSMAX+46*NSSMAX+23*NSMAX+23*NTRMAX 000370 0000
C MINARR=74*NTSMAX+46*NSSMAX+23*NSMAX+23*NTRMAX 000380 0000
C IF(MM.LT.MINARR) GO TO 500 000390 0000
C ----- 000400 0000
C 10 IERROR=0 000410 0000
C READ(LI,1,END=600) TITLE,LIST,PM,OM,STABEG 000420 0000
C WRITE(LO,2) TITLE 000430 0000
C WRITE(LO,3) PM,OM 000440 0000
C WRITE(LO,4) 000450 0000
C CALL INPUT (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5), 000460 0000
C INTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX) 000465 0000
C IF(ISTOP.EQ.1) GO TO 10 000470 0000
C 140 CALL SFTSET (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5), 000480 0000
C INTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX) 000485 0000
C IF(ISTOP.EQ.1) GO TO 10 000490 0000
C CALL LENGTH (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5), 000500 0000
C 1 ARRAY(J6),NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX) 000510 0000
C ----- 000520 0000
C PRINT OUT INPUT DATA FOR TUNNELS 000530 0000
C INITIALIZE 000540 0000

```

(Continued)

COSTUN Listing (Continued)

	IPR=0	000550 0000
	NLINES=40	000560 0000
	DO 5 M=1,NTS	
	I=M	
	ITYPE=1	000580 0000
	5 CALL INOUT (I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000590 0000
	1NLSMAX,IPR,NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000600 0000
C	PRINT OUT INPUT DATA FOR SHAFTS	000610 0000
C	INITIALIZE	000620 0000
	IPS=0	000630 0000
	NLINES=45	000640 0000
	DO 6 M=1,NSS	
	I=M	
	ITYPE=2	000660 0000
	6 CALL INOUT (I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000670 0000
	1NLSMAX,IPS,NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000680 0000
C	-----	000690 0000
C	CALCULATE TUNNEL DIMENSIONS	000700 0000
	DO 7 M=1,NTS	
	I=M	
	7 CALL SIZEST(I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000720 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000725 0000
C	CALCULATE SHAFT DIMENSIONS	000730 0000
	DO 8 M=1,NSS	
	I=M	
	8 CALL SIZESS(I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000750 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000755 0000
C	-----	000760 0000
C	DETERMINE STABILITY NUMBER AND EXCAVATION METHOD FOR SG TUNNELS	000770 0000
	DO 20 M=1,NTS	
	I=M	
	ITYPE=1	000790 0000
	CALL STABIL(I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000800 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000805 0000
C	20 CONTINUE	000810 0000
	DETERMINE STABILITY NUMBER AND EXCAVATION METHOD FOR SG SHAFTS	000820 0000
	DO 25 M=1,NSS	
	ITYPE=2	000840 0000
	I=M	
	CALL STABIL(I,ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000850 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000855 0000
C	25 CONTINUE	000860 0000
	-----	000870 0000
	CALL REACHD (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000880 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000885 0000
	CALL ADRATE (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000890 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000895 0000
	CALL CONSTM (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000900 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000905 0000
	CALL PUMPH (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000910 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000915 0000
	CALL PUMPR (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000920 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000925 0000
	CALL VOLUME (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000930 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000935 0000
	CALL EXCUOL (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000940 0000
	1NLSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)	000945 0000
	CALL MUCKLD (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),	000950 0000

(Continued)

COSTUN Listing (Continued)

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INTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX,NTRMAX)
CALL AIRLOK (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),
1 ARRAY(J6),NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)
CALL CALCS (ARRAY(J1),ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),
1NTSMAX,NSSMAX,NPMAX,NSMAX,NTRMAX)
IF(IERROR.EQ.1) GO TO 10
CALL COSTTU (ARRAY(J1),ARRAY(J3),ARRAY(J4),ARRAY(J5),ARRAY(J6),
1NTSMAX,NPMAX,NSMAX,NTRMAX,NSSMAX)
CALL COSTSF (ARRAY(J2),ARRAY(J3),ARRAY(J4),ARRAY(J5),
1NSSMAX,NPMAX,NSMAX,NTRMAX,NTSMAX)
CALL NEXSET(LO,LI)
GO TO 10
-----
DIMENSION OF 'ARRAY' ARRAY LESS THAN MINIMUM REQUIRED DIMENSION,
EXECUTION TERMINATED
500 WRITE(LO,9) MM,MINARR
-----
1 FORMAT(10(16A4//,40I1//,3F10.0)
2 FORMAT(1H1,10(//,15X,90(1H//,15X,1H,88X,1H//,
110(15X,1H,12X,16A4,12X,1H//,
2 15X,1H,88X,1H//,15X,90(1H//)
3 FORMAT(////,44X,32(1H//,
1 44X,1H,22H PROFIT MARGIN .....F7.2,2H *//,
2 44X,1H,22H OVERHEAD MARGIN .....F7.2,2H *//,
3 44X,32(1H//)
4 FORMAT(1H1)
9 FORMAT(1H1,////,1X,131(1H//27X,78H***** EXECUTION OF 'COSTUN' S
1TOPPED BECAUSE OF ERROR IN MAINLINE PROGRAM *****//22X,
213DIMENSION OF ,I7,68H GIVEN FOR 'ARRAY' IN MAINLINE PROGRAM IS L
3ESS THAN MINIMUM REQUIRED//22X, 13DIMENSION OF ,I7,
429H. ALL DATA DECKS IGNORED.//1X,131(1H//)
-----
500 CONTINUE
STOP
END
SUBROUTINE INPUT(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
1NTRMAX)
-----
THE FOLLOWING DEFINES THE CONTENTS OF THE VARIOUS ARRAYS
-----
CNP(I,J) .... NODAL POINT ARRAY (I = NODAL POINT NUMBER)
J = 1 STATIONING OF THE NODAL POINT
(CALCULATED IN SUB LENGTH)
= 2 ELEVATION OF THE NODAL POINT
A(I,J) ..... TUNNEL SEGMENT ARRAY (I = LOCATION OF SEGMENT IN
'A' ARRAY, J = AS BELOW)
ITEM J = 1 SEGMENT NUMBER = NTSEG
2 NODAL POINT TO LEFT OF SEGMENT = NPL
3 NODAL POINT TO RIGHT OF SEGMENT = NPR
4 REACH NUMBER = NREACH
5 ROCK STRENGTH = RS OR JRS
6 R.Q.D. = ROD OR JRQD
7 EXCAVATION METHOD = MEX
(1-DRILL AND BLAST, 2-MOLE(ROCK),
3-MOLE(SOIL), 4-HAND, 5-RIPPER
6-OPEN CUT(VERTICAL), 7-OPEN CUT
(SLOPING))

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(Continued)

COSTUN Listing (Continued)

8	HEADING ADVANCE RATE • AR	001490	0000
9	GROUNDWATER INFLOW AT WORKING FACE	001490	0000
	• INFLOW OR GI	001500	0000
10	LINING TYPE • LINING	001510	0000
	(0 OR BLANK=UNLINED, 1=CIP CONCRETE,	001520	0000
	2=SHOTCRETE, 3=PRECAST CONCRETE BOX)	001530	0000
11	LINING THICKNESS • TL OR LT OR TSEG	001540	0000
12	ROCK TEMPERATURE • RTEMP OR JRTEMP	001550	0000
13	SUPPRESSION OF FORMWORK COSTS=NOFORM	001560	0000
	(0 OR BLANK=POSSIBLE COSTS, 1=SUPPRESS	001570	0000
14	GROUNDWATER ELEVATION • ELWATR	001580	0000
15	WATERTIGHT LINING REQUIREMENT • LINWT	001590	0000
	(0 OR BLANK=NO, 1=WATERTIGHT)	001600	0000
16	TUNNEL SEGMENT TYPE • NTSTYP	001610	0000
	(1=ROCK, 2=SOFT GROUND,	001620	0000
	3= CUT AND COVER)	001630	0000
17	SURFACE NODAL POINT TO LEFT OF TUNNEL	001640	0000
	SEGMENT • NPLS	001650	0000
18	SURFACE NODAL POINT TO RIGHT OF	001660	0000
	TUNNEL SEGMENT • NPRS	001670	0000
19	EFFECTIVE GRAIN SIZE • D10	001680	0000
20	ANGLE OF INTERNAL FRICTION • PHI	001690	0000
21	SOIL COHESION • COHESN	001700	0000
22	SOIL UNIT WEIGHT • GAMMA	001710	0000
23	DEWATERING ALLOWED • IWATER	001720	0000
	(0 OR BLANK=NO, 1=ALLOWED)	001730	0000
24	ELEVATION OF IMPERVIOUS LAYER • ELIMP	001740	0000
25	SOIL PERMEABILITY • PERM	001750	0000
26	SUPPORT TYPE • ISUPPT	001760	0000
	(1=CAST IRON SEGMENTS, 2=CONCRETE	001770	0000
	SEGMENTS, 3=STEEL SEGMENTS,	001780	0000
	4=STEEL RIBS W/LINING, 5=SOLDIER	001790	0000
	PILE-LAGGING, 6=SLURRY WALL)	001800	0000
27	ELEVATION OF SOUND ROCK • ELROCK	001810	0000
28	OPEN CUT BRACING REQUIREMENT • IBRACE	001820	0000
	(0 OR BLANK=NONE, 1=STRUTS	001830	0000
	2=ANCHORS, 3=STRUTS+ANCHORS)	001840	0000
29	OPEN CUT DECKING REQUIREMENT • IDECK	001850	0000
	(0 OR BLANK=NO, 1=DECKING USED)	001860	0000
30	STABILITY NUMBER • STABNO	001870	0000
31	STABILIZATION METHOD • MSTAB	001880	0000
	(0 OR BLANK=NONE, 1=COMPRESSED	001890	0000
	AIR, 2=DEWATERING, 3=GROUND INJ.)	001900	0000
32	USE OF STABILIZATION METHOD • MUST	001910	0000
	(1=COSTUN SELECT, 2=COSTUN SELECT	001920	0000
	ONLY IF COULD NOT BE EXCAVATED,	001930	0000
	3=USER SELECT ONLY IF COULD NOT	001940	0000
	BE EXCAVATED, 4=USER SELECTS, MUST	001950	0000
	USE, EVEN IF MSTAB=0)	001960	0000
33	AIR PRESSURE • AIRPR	001970	0000
34	ACCEPTABLE INPUT STABIL.METHOD • MSTAC	001980	0000
	(1=ACCEPTABLE, 2=UNACCEPTABLE)	001990	0000
35	MAX AIR QUANTITY FOR COMPRESSED AIR	002000	0000
	SETUP • CAUT	002010	0000
36	NODAL POINT OF AIR LOCK • NPLOCK	002020	0000
37	MAX HEAT EXCHANGE FOR COOLING PLANT	002030	0000
	SETUP • QT	002040	0000
38	FOR ROCK OR SOFT GROUND -----	002050	0000

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[illegible]

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COSTUN Listing (Continued)

	CUT AND COVER BOX)	003220	0000
11	LINING THICKNESS = TL OR LT OR TSEG	003230	0000
12	SUPPRESSION OF FORMWORK COSTS = NOFCRM	003240	0000
	(0 OR BLANK = POSSIBLE COSTS, 1 = SUPPRESS	003250	0000
13	GROUNDWATER ELEVATION = ELLATR	003260	0000
14	WATERTIGHT LINING REQUIREMENT = LINUT	003270	0000
	(0 OR BLANK = NO, 1 = WATERTIGHT)	003280	0000
15	SHAFT SEGMENT TYPE = NSSTYP	003290	0000
	(1 = ROCK, 2 = SOFT GROUND,	003300	0000
	3 = CUT AND COVER)	003310	0000
16	EFFECTIVE GRAIN SIZE = D10	003320	0000
17	SOIL COHESION = COHESN	003330	0000
18	SOIL UNIT WEIGHT = GAMMA	003340	0000
19	ANGLE OF INTERNAL FRICTION = PHI	003350	0000
20	ELEVATION OF IMPERVIOUS LAYER = ELIMP	003360	0000
21	DEWATERING ALLOWED = IWATER	003370	0000
	(0 OR BLANK = NO, 1 = ALLOWED)	003380	0000
22	SUPPORT TYPE = ISUPPT	003390	0000
	(1 = CAST IRON	003400	0000
	SEGMENTS, 2 = CONCRETE SEGMENTS,	003410	0000
	3 = STEEL SEGMENTS, 4 = STEEL RIBS W.	003420	0000
	LINING, 5 = OPEN CUT)	003430	0000
23	SOIL PERMEABILITY = PERM	003440	0000
24	STABILITY NUMBER = STABNO	003450	0000
25	STABILIZATION METHOD = MSTAB	003460	0000
	(0 OR BLANK = NONE, 1 = COMPRESSED	003470	0000
	AIR, 2 = DEWATERING, 3 = GROUND INJ.)	003480	0000
26	USE OF STABILIZATION METHOD = MUST	003490	0000
	(1 = COSTUN SELECT, 2 = COSTUN SELECT	003500	0000
	ONLY IF COULD NOT BE EXCAVATED,	003510	0000
	3 = USER SELECT ONLY IF COULD NOT	003520	0000
	BE EXCAVATED, 4 = USER SELECTS, MUST	003530	0000
	USE, EVEN IF MSTAB = 0)	003540	0000
27	AIR PRESSURE = AIRPR	003550	0000
28	ACCEPTABLE INPUT STABIL. METHOD = MSTAC	003560	0000
	(1 = ACCEPTABLE, 2 = UNACCEPTABLE)	003570	0000
29	CHAR. EXC. DIMENSION = BE	003580	0000
30	FOR ROCK -----	003590	0000
	CHAR. EXC. DIMENSION AT RQD = 40 = BE40	003600	0000
	FOR SOFT GROUND -----	003610	0000
	SOIL LOAD = PSOIL	003620	0000
31	FOR ROCK -----	003630	0000
	CHAR. EXC. DIMENSION AT RQD = 60 = BE60	003640	0000
	FOR SOFT GROUND -----	003650	0000
	PSOIL + PUATER = PTOTAL	003660	0000
32	CHAR. EXC. DIM. W/OB = BOB	003670	0000
33	CHAR. EXC. DIM. W/OB, RQD = 40 = BOB40	003680	0000
34	CHAR. EXC. DIM. W/OB, RQD = 60 = BOB60	003690	0000
35	SEGMENT LENGTH = SSEGL	003700	0000
36	HOISTING HEIGHT = HH OR SEGDEP	003710	0000
37	MUCK LOADING RATE IN SEGMENT = RML	003720	0000
38	EXCAVATED VOLUME = U	003730	0000
39	ULTIMATE ADVANCE RATE = ARSULT	003740	0000
40	CONSTR. TIME EXC. + LINING = CTSS	003750	0000
41	CHAR. DEPTH OF SUPPORTS = WEB/ TPLATE	003760	0000
42	PUMPING FLOW, ONE DEEP WELL = FLOWL	003770	0000
43	WATER LOAD = PUATER	003780	0000
		003790	0000

(Continued)

COSTUN Listing (Continued)

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SHAFT(I,J) .. SHAFT INFORMATION (I=SHAFT NUMBER)
ITEM J = 1 LOCATION IN THE 'B' ARRAY IN WHICH -H 003800 0000
FIRST SHAFT SEGMENT OF SHAFT I IS 003810 0000
STORED = NSSEG1 003820 0000
2 NODAL POINT AT TOP OF SHAFT = NPTS 003830 0000
3 NODAL POINT AT BOTTOM OF SHAFT = NPBS 003840 0000
4 NUMBER OF SEGMENTS IN THIS SHAFT 003850 0000
= NSEGS 003860 0000
5 DISTANCE TO THE DISPOSAL SITE = DDS 003870 0000
6 COST OF DISPOSAL SITE = CDS OR ICDS 003880 0000
SHAFT SIZE = BF 003890 0000
8 DEPTH OF SHAFT 003900 0000
9 TOTAL VOLUME OF EXCAVATED MATERIAL 003910 0000
TOTAL VOLUME OF EXCAVATED MATERIAL 003920 0000
TO BE TAKEN OUT THRU THIS SHAFT 003930 0000
10 PEAK MUCK REMOVAL RATE SHAFT (CY/HR) 003940 0000
= RMLMAX OR IPRML 003950 0000
11 AVERAGE SUMMER ABOVE GROUND AIR 003960 0000
TEMPERATURE AT TOP OF SHAFT = AIRTEM 003970 0000
OR IARTEM 003980 0000
12 COST FACTOR FOR LABOR = CFL 003990 0000
13 COST FACTOR FOR EQUIPMENT = CFE 004000 0000
14 COST FACTOR FOR MATERIALS = CFM 004010 0000
15 REGIONAL COST FACTOR = RCF 004020 0000
16 SHAFT SHAPE = ISHAPS 004030 0000
(0 OR BLANK=DUMMY, 1=CIRCULAR,
2=SQUARE) 004040 0000
17 WORK HOURS PER DAY = HOURS 004050 0000
18 WORK DAYS PER WEEK = DAYS 004060 0000
19 TOTAL COST OF LABOR IN SHAFT = SCL 004070 0000
20 TOTAL COST OF EQUIP IN SHAFT = SCE 004080 0000
21 TOTAL COST OF MATERIAL IN SHAFT = SCM 004090 0000
22 TOTAL COST OF SHAFT = SCT 004100 0000
23 PORTALS = NPORT 004110 0000
(0=TRUE SHAFT,1=PORTAL) 004120 0000
LIST(I) ..... ARRAY OF PRINTOUT OPTIONS 004130 0000
ITEM I = 1 NODAL POINT ELEVATIONS 004140 0000
2 TUNNEL INPUT DATA 004150 0000
3 SHAFT INPUT DATA 004160 0000
4 CALCULATED TUNNEL DATA 004170 0000
5 CALCULATED SHAFT DATA 004180 0000
6 TUNNEL SEGMENT AND REACH COSTS 004190 0000
7 SHAFT SEGMENT AND SHAFT COSTS 004200 0000
8 TUNNEL REACH COST SUMMARY 004210 0000
9 SHAFT COST SUMMARY 004220 0000
10-40 UNUSED AT PRESENT 004230 0000
IF THE VALUE OF LIST(I) IS ZERO OR BLANK, LISTING OF 004240 0000
ITEM WILL OCCUR. IF VALUE IS ONE, LISTING WILL BE 004250 0000
SUPPRESSED. ITEM NUMBER IS SAME AS DATA CARD COLUMN 004260 0000
NUMBER. 004270 0000
004280 0000
004290 0000
004300 0000
004310 0000
004320 0000
004330 0000
***** INPUT TUNNEL SYSTEM LOCATIONS AND CHARACTERISTICS * 004340 0000
004350 0000
004360 0000

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(Continued)

COSTUN Listing (Continued)

C	-----	004370	0000
	COMMON /BASIC/ NSS,NTS	004380	0000
	COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEQ,ITYPE	004390	0000
	COMMON /F/ IERROR,ISTOP	004400	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	004410	0000
	1 TRDATA(NTRMAX,23)	004420	0000
C	-----	004430	0000
C		004440	0000
C		004450	0000
	ISTOP=0	004460	0000
C	*****	004470	0000
C		004480	0000
	IPR=0	004490	0000
C	READ NODAL POINTS AND STORE IN CORE *****	004500	0000
C		004510	0000
C	INITIALIZE NODAL POINT ARRAY	004520	0000
	DO 15 I=1,NPMAX	004530	0000
15	CNP(I,2)=-10.E30	004540	0000
C		004550	0000
	N=NODAL POINT NUMBER, Y=NODAL POINT ELEVATION	004560	0000
20	READ(LI,1000) N,Y	004570	0000
C	CHECK FOR MISSING SEPARATOR CARD	004580	0000
	IF (Y.LT.50000.) GO TO 21	004590	0000
	ISTOP = 1	004600	0000
	WRITE (LO,1500)	004610	0000
	GO TO 425	004620	0000
21	CONTINUE	004630	0000
C	CHECK FOR END OF NODAL POINT COORDINATES	004640	0000
	IF(N.EQ.9999) GO TO 30	004650	0000
	IF(N.GT.NPMAX.OR.N.LE.0) GO TO 25	004660	0000
C		004670	0000
C	CHECK FOR PREVIOUS DEFINITION OF THIS NODAL POINT	004680	0000
	IF(CNP(N,2).GT.-10.E29) ISTOP=1	004690	0000
	IF(CNP(N,2).GT.-10.E29) WRITE (LO,1013) N	004700	0000
	CNP(N,2)=Y	004710	0000
	GO TO 20	004720	0000
25	WRITE(LO,1001) N,NPMAX	004730	0000
	ISTOP=1	004740	0000
	GO TO 20	004750	0000
C	END OF NODAL POINT INPUT	004760	0000
30	CONTINUE	004770	0000
C		004780	0000
C	*****	004790	0000
C		004800	0000
C	READ TUNNEL SEGMENT INFORMATION AND STORE *****	004810	0000
C		004820	0000
C	INITIALIZE TUNNEL SEGMENT ARRAY	004830	0000
	DO 40 I=1,NTSMAX	004840	0000
40	A(I,1)=-10.E30	004850	0000
C	INITIALIZE THE REACH ARRAY	004860	0000
	DO 41 I=1,NTRMAX	004870	0000
41	TRDATA(I,1)=-10.E30	004880	0000
C		004890	0000
C	I=SEGMENT SEQUENCE NUMBER	004900	0000
	I=0	004910	0000
50	I=I+1	004920	0000
C	-----	004930	0000
C		004940	0000

(Continued)

CQSTUN Listing (Continued)

C	004940 0000 CHECK FOR MAX NUMBER OF SEGMENT CARDS IF(I.LE.NTSMAX) GO TO 52	004550 0000 004950 0000 004570 0000
C	----- CHECK FOR END OF TUNNEL SEGMENT DATA. NDUM=DUMMY SEGMENT NUMBER	004980 0000
C	51 READ(LI,1020) NDUM	004590 0000
	IF(NDUM.EQ.9999) GO TO 75	005000 0000
	WRITE(LO,1016) NTSMAX	005010 0000
	ISTOP=1	005020 0000
	GO TO 51	005030 0000
C	-----	005040 0000
C	52 CONTINUE	005050 0000
C	READ SEGMENT DATA FROM CARD	005060 0000
	READ(LI,1005) (A(I,J),J=1,3),A(I,45) ,(A(I,J),J=4,16)	005070 0000
	NTSEG=A(I,1)	005080 0000
	NREACH=A(I,4)	005090 0000
	NTSTYP=A(I,16)	005100 0000
C	-----	005110 0000
C	CHECK FOR LAST TUNNEL CARD	005120 0000
	IF(NTSEG.EQ.9999) GO TO 75	005130 0000
C	CHECK FOR MISSING SEPARATOR CARD	005140 0000
	IF(NTSTYP.NE.0) GO TO 53	005150 0000
	ISTOP = 1	005160 0000
	WRITE(LO,1501)	005170 0000
	53 CONTINUE	005180 0000
C	-----	005190 0000
C	CHECK FOR PROPER TUNNEL TYPE CODE	005200 0000
	IF(NTSTYP.GE.1.AND.NTSTYP.LE.3) GO TO 530	005210 0000
	ISTOP=1	005220 0000
	WRITE(LO,2000) NTSEG,NREACH	005230 0000
	GO TO 425	005240 0000
	530 CONTINUE	005250 0000
C	-----	005260 0000
C	READ SECOND SEGMENT DATA CARD IF NOT ROCK TUNNEL	005270 0000
	IF(NTSTYP.GT.1) READ(LI,1006) (A(I,J),J=17,33)	005280 0000
C	-----	005290 0000
C	CHECK FOR PREVIOUS USE OF REACH NUMBER	005300 0000
	IF(I.EQ.1) GO TO 535	005310 0000
	IF(NREACH.EQ.IPR) GO TO 54	005320 0000
	IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 535	005330 0000
	WRITE(LO,1022) NTSEG,NREACH	005340 0000
	ISTOP=1	005350 0000
	535 TRDATA(NREACH,1)=0.	005360 0000
	54 CONTINUE	005370 0000
C	-----	005380 0000
C	CHECK THAT TUNNEL SEGMENT CARDS HAVE BEEN PROPERLY ARRANGED	005390 0000
	IF(I.EQ.1) GO TO 57	005400 0000
	56 IF(A(I,2).EQ.A(I-1,3)) GO TO 57	005410 0000
	WRITE(LO,1015) NTSEG,NREACH	005420 0000
	ISTOP=1	005430 0000
	57 CONTINUE	005440 0000
C	-----	005450 0000
C	CHECK THAT ALL TUNNEL NODAL POINTS HAVE BEEN INPUT	005460 0000
	NPL=A(I,2)	005470 0000
	NPR=A(I,3)	005480 0000
	ELNPL=CNP(NPL,2)	005490 0000
	ELNPR=CNP(NPR,2)	005500 0000
		005510 0000

(Continued)

COSTUN Listing (Continued)

C	ELAUG=(ELNPL+ELNPR)/2.	005520	0000
	BYPASS CHECK FOR NOTAL INPUT		
	GO TO 58		
	IF(ELNPL.GT.-10.E29.AND.ELNPR.GT.-10.E29) GO TO 58	005530	0000
	WRITE(LO,1031) NTSEG,NREACH	005540	0000
	ISTOP=1	005550	0000
58	CONTINUE	005560	0000
C	-----	005570	0000
C	CHECK FOR PROPER EXCAVATION METHODS IN TUNNEL SEGMENTS	005580	0000
	MEX=A(I,7)	005590	0000
	IF(MEX.GE.1.AND.MEX.LE.7) GO TO 65	005600	0000
	ISTOP=1	005610	0000
	WRITE(LO,1030) NTSEG,NREACH	005620	0000
65	CONTINUE	005630	0000
C	-----	005640	0000
C	CHECK FOR PROPER EXCAVATION METHOD FOR TUNNEL TYPE SPECIFIED	005650	0000
	IF(NTSTYP.EQ.1.AND.MEX.GT.2) GO TO 650	005660	0000
	IF(NTSTYP.EQ.2.AND.MEX.LT.3.OR.NTSTYP.EQ.2.AND.MEX.GT.5) GO TO 650	005670	0000
	IF(NTSTYP.EQ.3.AND.MEX.LT.6) GO TO 650	005680	0000
	GO TO 655	005690	0000
650	ISTOP=1	005700	0000
	WRITE(LO,2005) NTSEG,NREACH	005710	0000
655	CONTINUE	005720	0000
C	-----	005730	0000
C	CHECK FOR CONTRADICTION OF SPECIFYING A THICKNESS FOR NO LINING	005740	0000
	LINING=A(I,10)	005750	0000
	IF(NTSTYP.NE.1.OR.LINING.NE.0) GO TO 67	005760	0000
	TL=A(I,11)	005770	0000
	IF(TL.LE.0.001) GO TO 67	005780	0000
	WRITE(LO,1045) NTSEG,NREACH	005790	0000
	ISTOP=1	005800	0000
67	CONTINUE	005810	0000
C	-----	005820	0000
C	CHECK FOR PROPER LINING TYPE CODE	005830	0000
C	BYPASS CHECK FOR PROPER LINING CODE		
	GO TO 70		
	IF(LINING.GE.0.AND.LINING.LE.3) GO TO 68	005840	0000
	WRITE(LO,1043) NTSEG,NREACH	005850	0000
	ISTOP=1	005860	0000
68	CONTINUE	005870	0000
C	-----	005880	0000
C	CHECK FOR PROPER LINING CODE FOR TUNNEL TYPE SPECIFIED	005890	0000
	IF(NTSTYP.LT.3.AND.LINING.NE.3.OR.NTSTYP.EQ.3.AND.LINING.EQ.1.OR.	005900	0000
	INTSTYP.EQ.3.AND.LINING.EQ.3) GO TO 70	005910	0000
	ISTOP=1	005920	0000
	WRITE(LO,2010) NTSEG,NREACH	005930	0000
C	-----	005940	0000
C	CHECK FOR ADVANCE RATE NOT SPECIFIED	005950	0000
70	AR=A(I,8)	005960	0000
	IF(AR.EQ.0.0) GO TO 71	005970	0000
C	-----	005980	0000
C	CHECK FOR ADVANCE RATE LESS THAN 0 FT/DAY	005990	0000
	IF(AR.GT.0.0) GO TO 71	006000	0000
	ISTOP=1	006010	0000
	WRITE(LO,1065) NTSEG,NREACH	006020	0000
C	-----	006030	0000
C	CHECK FOR ROCK STRENGTH GREATER THAN 500 PSI	006040	0000
71	RS=A(I,5)	006050	0000

(Continued)

COSTUN LISTING (Continued)

	IF(RS.LT.500..AND.NTSTYP.EQ.1) WRITE(LO,1060) NTSEG,NREACH	006060 0000
C	-----	006070 0000
C	CHECK FOR PROPER WATERTIGHT CODE	006080 0000
	LINUT=A(I,15)	006090 0000
	IF(LINUT.EQ.0.OR.LINUT.EQ.1) GO TO 710	006100 0000
	ISTOP=1	006110 0000
	WRITE(LO,2015) NTSEG,NREACH	006120 0000
710	CONTINUE	006130 0000
C	-----	006140 0000
C	ALL CUT AND COVER BOX SEGMENTS ARE DESIGNED AS WATERTIGHT -	006150 0000
C	INPUT IGNORED	006160 0000
C	IF(NTSTYP.EQ.3.AND.LINUT.EQ.0) WRITE(LO,2017) NTSEG,NREACH	006170 0000
C	-----	006180 0000
C	A LINING OR SUPPORT MUST BE SPECIFIED WHEN WATERTIGHTNESS REQUIRED	006190 0000
	ISUPPT=A(I,26)	006200 0000
	IF(LINUT.EQ.0.OR.LINUT.GT.0) GO TO 711	006210 0000
	IF(NTSTYP.GT.1.AND.ISUPPT.LE.3) GO TO 711	006220 0000
	ISTOP=1	006230 0000
	WRITE(LO,2020) NTSEG,NREACH	006240 0000
C	-----	006250 0000
C	CHECK IF GROUNDWATER ELEVATION NOT INPUT AND WATERTIGHT REQUIRED	006260 0000
711	ELWATR=A(I,14)	006270 0000
	IF(LINUT.EQ.1.AND.ELWATR.EQ.0.) WRITE(LO,2025) NTSEG,NREACH	006280 0000
C	-----	006290 0000
C	CHECK IF TUNNEL TYPE NOT ROCK AND GROUNDWATER ELEV. NOT SPECIFIED	006300 0000
C	IF(NTSTYP.GT.1.AND.ELWATR.EQ.0) WRITE(LO,2025) NTSEG,NREACH	006310 0000
C	-----	006320 0000
C	CHECK FOR PROPER TUNNEL CODE IF RQD IS LESS THAN 25.	006330 0000
	RQD=A(I,6)	006340 0000
	IF(NTSTYP.GT.1.OR.RQD.GE.25.)GO TO 712	006350 0000
	ISTOP=1	006360 0000
	WRITE(LO,2030) NTSEG,NREACH	006370 0000
712	CONTINUE	006380 0000
C	-----	006390 0000
C	IS TUNNEL IN SOFT GROUND AND RQD GREATER THAN 25.	006400 0000
C	IF(NTSTYP.EQ.2.AND.RQD.GT.25.) WRITE(LO,2035) NTSEG,NREACH	006410 0000
C	-----	006420 0000
C	CHECK FOR RQD BETWEEN 0 AND 100.	006430 0000
	IF(RQD.GE.0.0.AND.RQD.LE.100.) GO TO 713	006440 0000
	WRITE(LO,1062) NTSEG,NREACH	006450 0000
	ISTOP=1	006460 0000
C	-----	006470 0000
C	CHECK REMAINING DATA IF TUNNEL IS NOT IN ROCK	006480 0000
713	IF(NTSTYP.EQ.1) GO TO 74	006490 0000
C	-----	006500 0000
C	CHECK THAT TUNNEL SURFACE NODAL POINTS HAVE BEEN PROPERLY ARRANGED	006510 0000
	IF(I.EQ.1) GO TO 7130	006520 0000
C	CHECK FOR PREVIOUS SEGMENT IN ROCK	006530 0000
	NSTYPE=A(I-1,16)	006540 0000
	IF(NSTYPE.EQ.1) GO TO 7130	006550 0000
	NPLS=A(I,17)	006560 0000
	NPRS=A(I-1,18)	006570 0000
	IF(NPLS.EQ.NPRS) GO TO 7130	006580 0000
	ISTOP=1	006590 0000
	WRITE(LO,2040) NTSEG,NREACH	006600 0000
C	-----	006610 0000
7130	NPLS=A(I,17)	006620 0000
	NPRS=A(I,18)	006630 0000

(Continued)

AD-A107 890

ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/6 13/13
TUNNEL COST-ESTIMATING METHODS.(U)

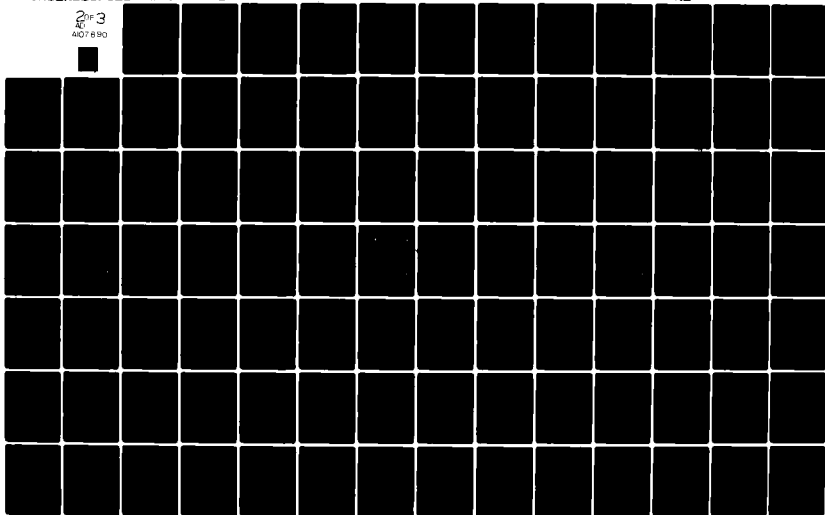
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COSTUN Listing (Continued)

	ELNPLS=CNP(NPLS,2)	006640	0000
	ELNPRS=CNP(NPRS,2)	006650	0000
C	CHECK THAT ALL TUNNEL SURFACE NODAL POINTS HAVE BEEN INPUT	006660	0000
	IF(ELNPLS.GT.-10.E29.AND.ELNPRS.GT.-10.E29) GO TO 714	006670	0000
	ISTOP=1	006680	0000
	WRITE(LO,2045) NTSEG,NREACH	006690	0000
714	CONTINUE	006700	0000
C	-----	006710	0000
C	CHECK THAT SURFACE NODAL POINT ELEVATIONS ARE ABOVE TUNNEL ELEV.	006720	0000
	IF(ELNPLS.GE.ELNPL.AND.ELNPRS.GE.ELNPR) GO TO 715	006730	0000
	ISTOP=1	006740	0000
	WRITE(LO,2050) NTSEG,NREACH	006750	0000
C	-----	006760	0000
C	CHECK IF EFFECTIVE GRAIN SIZE IS INPUT	006770	0000
715	D10=A(I,19)	006780	0000
	IF(D10.GT.0) GO TO 716	006790	0000
	ISTOP=1	006800	0000
	WRITE(LO,2055) NTSEG,NREACH	006810	0000
C	-----	006820	0000
C	CHECK THAT PHI AND/OR COHESION ARE SPECIFIED	006830	0000
716	PHI=A(I,20)	006840	0000
	COHESN=A(I,21)	006850	0000
	IF(PHI.GT.0.OR.COHESN.GT.0) GO TO 7160	006860	0000
	ISTOP=1	006870	0000
	WRITE(LO,2060) NTSEG,NREACH	006880	0000
7160	CONTINUE	006890	0000
C	-----	006900	0000
C	CHECK FOR POSSIBLE ERROR IN PERMEABILITY INPUT	006910	0000
	PERM=A(I,25)	006920	0000
	IF(PERM.GT.10) WRITE(LO,2061) NTSEG,NREACH	006930	0000
C	-----	006940	0000
C	CHECK IF PHI GREATER THAN 45 - WARNING, OR GREATER THAN 100 -ERROR	006950	0000
	IF(PHI.GT.45.) WRITE(LO,2062) NTSEG,NREACH	006960	0000
	IF(PHI.LT.100.) GO TO 7165	006970	0000
	ISTOP=1	006980	0000
	WRITE(LO,2063) NTSEG,NREACH	006990	0000
C	-----	007000	0000
C	CHECK IF GAMMA GREATER THAN 200	007010	0000
7165	GAMMA=A(I,22)	007020	0000
	IF(GAMMA.LE.200.) GO TO 717	007030	0000
	ISTOP=1	007040	0000
	WRITE(LO,2064) NTSEG,NREACH	007050	0000
C	-----	007060	0000
C	CHECK FOR PROPER DEWATERING CODE	007070	0000
717	IWATER=A(I,23)	007080	0000
	IF(IWATER.EQ.0.OR.IWATER.EQ.1) GO TO 7170	007090	0000
	ISTOP=1	007100	0000
	WRITE(LO,2065) NTSEG,NREACH	007110	0000
C	-----	007120	0000
C	CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT	007130	0000
7170	IF(NTSTYP.EQ.3) GO TO 718	007140	0000
	MSTAB=A(I,31)	007150	0000
	MUST=A(I,32)	007160	0000
	IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 7185	007170	0000
	IF(IWATER.EQ.0.OR.PERM.LT.10.E-10.AND.D10.LE.0.08.OR.PERM.GT.	007180	0000
	110.E-10.AND.PERM.LE.0.0006) GO TO 7185	007190	0000
C	-----	007200	0000
C	CHECK IF DEWATERING ALLOWED AND IMPERVIOUS LAYER NOT SPECIFIED	007210	0000

(Continued)

COSTUN Listing (Continued)

C	OR IMPERVIOUS LAYER NOT SPECIFIED FOR CUT AND COVER	007220	0000
718	ELIMP=A(I,24)	007230	0000
	IF(ELIMP.EQ.0.0) WRITE(LO,2070) NTSEG,NREACH	007240	0000
C	-----	007250	0000
C	CHECK IF IMPERVIOUS LAYER ELEVATION IS BELOW SURFACE ELEVATION	007260	0000
	ELSURF=(ELNPLS+ELNPRS)/2.	007270	0000
	IF(ELIMP.LE.ELSURF) GO TO 7180	007280	0000
	ISTOP=1	007290	0000
	WRITE(LO,2072) NTSEG,NREACH	007300	0000
7180	CONTINUE	007310	0000
C	-----	007320	0000
C	CHECK IF OPEN CUT IS ENTIRELY IN ROCK	007330	0000
	ELROCK=A(I,27)	007340	0000
	IF(NTSTYP.EQ.3.AND.ELROCK.EQ.ELSURF) GO TO 7185	007350	0000
C	-----	007360	0000
C	CHECK IF IMPERVIOUS LAYER IS AT THE SURFACE AND GRAIN SIZE INPUT	007370	0000
C	DOES NOT INDICATE A CLAY.	007380	0000
	IF(ELIMP.LT.ELSURF.OR.D10.LE.0.005) GO TO 7185	007390	0000
	ISTOP=1	007400	0000
	WRITE(LO,2073) NTSEG,NREACH	007410	0000
7185	CONTINUE	007420	0000
C	-----	007430	0000
	IF(MEX.EQ.7) GO TO 7205	007440	0000
C	CHECK FOR PROPER SUPPORT CODE	007450	0000
	IF(ISUPPT.GE.1.AND.ISUPPT.LE.6) GO TO 719	007460	0000
	ISTOP=1	007470	0000
	WRITE(LO,2075) NTSEG,NREACH	007480	0000
719	CONTINUE	007490	0000
C	-----	007500	0000
C	CHECK FOR PROPER SUPPORT CODE FOR TUNNEL TYPE SPECIFIED	007510	0000
	IF(NTSTYP.EQ.2.AND.ISUPPT.LE.4.OR.NTSTYP.EQ.3.AND.ISUPPT.GT.4)	007520	0000
	1GO TO 720	007530	0000
	ISTOP=1	007540	0000
	WRITE(LO,2080) NTSEG,NREACH	007550	0000
720	CONTINUE	007560	0000
C	-----	007570	0000
C	CHECK FOR PROPER LINING CODE FOR SUPPORT TYPE SPECIFIED	007580	0000
	IF(ISUPPT.LE.3.AND.LINING.EQ.0) GO TO 7205	007590	0000
	IF(ISUPPT.GT.3.AND.LINING.EQ.0) GO TO 7200	007600	0000
	IF(ISUPPT.EQ.4.AND.LINING.NE.3) GO TO 7205	007610	0000
	IF(ISUPPT.GT.4.AND.LINING.NE.2) GO TO 7205	007620	0000
7200	ISTOP=1	007630	0000
	WRITE(LO,2085) NTSEG,NREACH	007640	0000
C	-----	007650	0000
C	CHECK IF SOFT GROUND TUNNEL	007660	0000
7205	IF(NTSTYP.EQ.2) GO TO 725	007670	0000
C	-----	007680	0000
C	CHECK FOR ROCK ELEV. IF TUNNEL IN CUT AND COVER	007690	0000
	IF(ELROCK.EQ.0.0) WRITE(LO,2090) NTSEG,NREACH	007700	0000
C	-----	007710	0000
C	CHECK IF ROCK ELEVATION IS BELOW GROUND SURFACE ELEVATION	007720	0000
	IF(ELROCK.LE.ELSURF) GO TO 7210	007730	0000
	ISTOP=1	007740	0000
	WRITE(LO,2092) NTSEG,NREACH	007750	0000
7210	CONTINUE	007760	0000
C	-----	007770	0000
C	CHECK IF BOX DEPTH IS GREATER THAN 100 FEET	007780	0000
	DTUN=ELSURF-ELAUG	007790	0000

(Continued)

COSTUN Listing (Continued)

C	IF(DTUN.GT.100.) WRITE(LO,2094) NTSEG,NREACH	007800	0000
C	-----	007810	0000
C	CHECK FOR PROPER BRACING CODE	007820	0000
	IBRACE=A(I,28)	007830	0000
	IF(IBRACE.GE.0.AND.IBRACE.LE.3) GO TO 723	007840	0000
	ISTOP=1	007850	0000
	WRITE(LO,2095) NTSEG,NREACH	007860	0000
723	CONTINUE	007870	0000
C	-----	007880	0000
C	CHECK IF CUT AND COVER (VERTICAL) AND BRACING CODE NOT SPECIFIED	007890	0000
	DROCK=ELSURF-ELROCK	007900	0000
	IF(IBRACE.GT.0.OR.MEX.NE.6.OR.DROCK.LT.0.1) GO TO 724	007910	0000
	ISTOP=1	007920	0000
	WRITE(LO,2100) NTSEG,NREACH	007930	0000
C	-----	007940	0000
C	CHECK FOR PROPER DECKING CODE	007950	0000
724	IDECK=A(I,29)	007960	0000
	IF(IDECK.EQ.0.OR.IDECK.EQ.1) GO TO 74	007970	0000
	ISTOP=1	007980	0000
	WRITE(LO,2105) NTSEG,NREACH	007990	0000
	GO TO 74	008000	0000
C	-----	008010	0000
C	CHECK FOR HIGH STABILITY NUMBER - MAY RESULT THAT JOB UNEXCAVATABLE	008020	0000
725	STABNO=A(I,30)	008030	0000
	IF(STABNO.LE.9.AND.PHI.LT.29.OR.STABNO.LE.7.AND.PHI.GE.29)	008040	0000
	1 GO TO 7250	008050	0000
	ISTOP=1	008060	0000
	WRITE(LO,2115) NTSEG,NREACH	008070	0000
C	-----	008080	0000
C	CHECK FOR PROPER STABILIZATION METHOD CODE	008090	0000
7250	MSTAB=A(I,31)	008100	0000
	IF(MSTAB.GE.0.AND.MSTAB.LE.3) GO TO 726	008110	0000
	ISTOP=1	008120	0000
	WRITE(LO,2120) NTSEG,NREACH	008130	0000
C	-----	008140	0000
C	CHECK FOR PROPER USE CODE FOR STABILIZATION METHOD	008150	0000
726	MUST=A(I,32)	008160	0000
	IF(MUST.GE.1.AND.MUST.LE.4) GO TO 727	008170	0000
	ISTOP=1	008180	0000
	WRITE(LO,2125) NTSEG,NREACH	008190	0000
C	-----	008200	0000
C	CHECK FOR AIR PRESSURE INPUT IF STABILITY NUMBER INPUT AND	008210	0000
	AIR PRESSURE STABILIZATION INPUT	008220	0000
727	AIRPR=A(I,33)	008230	0000
	IF(STABNO.GT.0.0.AND.MSTAB.EQ.1.AND.AIRPR.EQ.0.0) GO TO 7270	008240	0000
	GO TO 728	008250	0000
7270	ISTOP=1	008260	0000
	WRITE(LO,2130) NTSEG,NREACH	008270	0000
728	CONTINUE	008280	0000
C	-----	008290	0000
C	CHECK FOR USE CODE *4 WHEN STABILITY NUMBER IS SPECIFIED	008300	0000
	IF(STABNO.EQ.0.0.OR.MUST.EQ.4) GO TO 729	008310	0000
	ISTOP=1	008320	0000
	WRITE(LO,2135) NTSEG,NREACH	008330	0000
729	CONTINUE	008340	0000
C	-----	008350	0000
C	CHECK IF STABILIZATION METHOD NOT COMPRESSED AIR BUT AIRPR GT 0	008360	0000
	IF(MSTAB.EQ.1.OR.AIRPR.EQ.0.) GO TO 7290	008370	0000
	ISTOP=1	008380	0000

(Continued)

COSTUN Listing (Continued)

	WRITE(LO,2137) NTSEG,NREACH	008390	0000
7290	CONTINUE	008400	0000
C	-----	008410	0000
C	CHECK IF STABILIZATION METHOD AGREES WITH USE CODE	008420	0000
C	IF(MSTAB.GE.0.AND.MUST.EQ.4.OR.MSTAB.GT.0.AND.MUST.EQ.3.OR.	008430	0000
C	1MSTAB.EQ.0.AND.MUST.LT.3) GO TO 730	008440	0000
C	ISTOP=1	008450	0000
C	WRITE(LO,2140) NTSEG,NREACH	008460	0000
730	CONTINUE	008470	0000
C	-----	008480	0000
C	CHECK IF STABILIZATION METHOD IS INPUT	008490	0000
C	IF(MSTAB.EQ.0) GO TO 74	008500	0000
C	-----	008510	0000
C	CHECK IF STABILIZATION METHOD IS ACCEPTABLE	008520	0000
C	GO TO (731,732,733), MSTAB	008530	0000
C	-----	008540	0000
C	AIR PRESSURE -- CHECK IF SOIL IS A GRAVEL	008550	0000
731	IF(PERM.LT.10.E-10.AND.D10.GT.2.) GO TO 734	008560	0000
C	IF(PERM.GT.0.4) GO TO 734	008570	0000
C	CHECK IF SOIL IS CLAY	008580	0000
C	IF(D10.LE.0.005) GO TO 737	008590	0000
C	CHECK IF TUNNEL ABOVE GROUND WATER TABLE	008600	0000
C	IF(ELWATR.LT.ELAUG) GO TO 737	008610	0000
C	CHECK IF WATER HEAD LESS THAN 115 FEET	008620	0000
C	IF(ELWATR-ELAUG.LE.115.) GO TO 737	008630	0000
C	GO TO 734	008640	0000
C	-----	008650	0000
C	DEWATERING -- CHECK IF DEWATERING IS ALLOWED	008660	0000
732	IF(IWATR.EQ.0) GO TO 734	008670	0000
C	IF(D10.LE.0.005) GO TO 734	008680	0000
C	CHECK IF TUNNEL IS ABOVE GROUND WATER TABLE	008690	0000
C	IF(ELWATR.LT.ELAUG) GO TO 734	008700	0000
C	CHECK IF SOIL IS FINE SAND OR COARSER OR IS REASONABLY PERMEABLE	008710	0000
C	IF(PERM.LT.10.E-10.AND.D10.GT.0.08) GO TO 737	008720	0000
C	IF(PERM.GT.0.0006) GO TO 737	008730	0000
C	GO TO 734	008740	0000
C	-----	008750	0000
C	GROUND INJECTIONS -- CHECK IF SOIL IS NOT CLAY	008760	0000
733	IF(D10.GT.0.005) GO TO 737	008770	0000
C	-----	008780	0000
C	STABILIZATION METHOD IS NOT ACCEPTABLE	008790	0000
734	MSTAC=2	008800	0000
C	CHECK IF USE CODE EQUALS 4	008810	0000
C	IF(MUST.EQ.4) GO TO 735	008820	0000
C	WRITE(LO,2145) NTSEG,NREACH	008830	0000
C	GO TO 738	008840	0000
735	ISTOP=1	008850	0000
C	WRITE(LO,2147) NTSEG,NREACH	008860	0000
C	GO TO 738	008870	0000
C	-----	008880	0000
C	STABILIZATION METHOD IS ACCEPTABLE	008890	0000
737	MSTAC=1	008900	0000
738	A(1,34)=MSTAC	008910	0000
74	IPR=NREACH	008920	0000
C	-----	008930	0000
C	GO TO 50	008940	0000
C	END OF TUNNEL SEGMENT DATA	008950	0000
75	CONTINUE	008960	0000

(Continued)

COSTUN Listing (Continued)

C	*****	008970	0000
C	NTS=I-1	008980	0000
C	*****	008990	0000
C		009000	0000
C		009010	0000
C	READ REACH DATA FOR TUNNELS	009020	0000
C		009030	0000
C	INITIALIZE REACH ARRAY	009040	0000
C	DO 80 I=1,NTRMAX	009050	0000
C	80 TRDATA(I,1)=-10.E30	009060	0000
C		009070	0000
C		009080	0000
C	-----	009090	0000
C	READ REACH DATA FROM CARD	009100	0000
C	81 READ (LI,1020) NREACH,NSHAFT,BFT,ISHAPE,MTM,HOURS,DAYS,NBOX,	009110	0000
C	1BFBWDT,BFBHT,IBOX2,ISEPCK	009120	0000
C	IF(NREACH.EQ.9999) GO TO 86	009130	0000
C	CHECK FOR MISSING SEPARATOR CARD	009140	0000
C	IF(ISEPCK.EQ.0) GO TO 82	009150	0000
C	ISTOP=1	009160	0000
C	WRITE (LO,1502)	009170	0000
C	GO TO 425	009180	0000
C	82 CONTINUE	009190	0000
C	IF(NREACH.LE.NTRMAX.AND.NREACH.GT.0) GO TO 84	009200	0000
C	WRITE(LO,1021) NREACH,NTRMAX	009210	0000
C	ISTOP=1	009220	0000
C	84 CONTINUE	009230	0000
C	-----	009240	0000
C	CHECK FOR FINISHED DIMENSION BETWEEN 10 AND 40 FEET	009250	0000
C	IF(ISHAPE.GT.0.AND.BFT.LT.10..OR.ISHAPE.GT.0.AND.BFT.GT.40.)	009260	0000
C	1WRITE(LO,1064) NREACH	009270	0000
C	-----	009280	0000
C	CHECK IF TUNNEL SIZE INPUT AGREES WITH SHAPE CODE	009290	0000
C	IF(BFT.EQ.0.AND.ISHAPE.EQ.0.OR.BFT.GT.0.AND.ISHAPE.GT.0) GO TO 840	009300	0000
C	ISTOP=1	009310	0000
C	IF(ISHAPE.GT.0) WRITE(LO,2150) NREACH	009320	0000
C	IF(ISHAPE.EQ.0) WRITE(LO,2151) NREACH	009330	0000
C	840 CONTINUE	009340	0000
C	-----	009350	0000
C	CHECK FOR PREVIOUS USE OF REACH NUMBER	009360	0000
C	IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 85	009370	0000
C	WRITE(LO,1026) NREACH	009380	0000
C	ISTOP=1	009390	0000
C	85 CONTINUE	009400	0000
C	-----	009410	0000
C	CHECK FOR PROPER MUCK TRANSPORT METHOD CODE	009420	0000
C	IF(MTM.GE.0.AND.MTM.LE.4) GO TO 850	009430	0000
C	WRITE(LO,1041) NREACH	009440	0000
C	ISTOP=1	009450	0000
C	850 CONTINUE	009460	0000
C	-----	009470	0000
C	CHECK FOR PROPER TUNNEL SHAPE CODE	009480	0000
C	IF(ISHAPE.GE.0.AND.ISHAPE.LE.3) GO TO 851	009490	0000
C	WRITE(LO,1042) NREACH	009500	0000
C	ISTOP=1	009510	0000
C	851 CONTINUE	009520	0000
C	-----	009530	0000
C	CHECK IF SHAPE CODE AGREES WITH MUCK TRANSPORT METHOD	009540	0000

(Continued)

COSTUN Listing (Continued)

	IF(ISHAPE.GT.0.AND.MTM.GT.0.OR.ISHAPE.EQ.0.AND.MTM.EQ.0) GO TO 852	009550	0000
	ISTOP=1	009560	0000
	IF(ISHAPE.EQ.0) WRITE(LO,2152) NREACH	009570	0000
	IF(ISHAPE.GT.0) WRITE(LO,2153) NREACH	009580	0000
852	CONTINUE	009590	0000
C	-----	009600	0000
C	CHECK IF WORK HOURS PER DAY IN PROPER RANGE	009610	0000
	IF(HOURS.GE.0..AND.HOURS.LE.24.) GO TO 853	009620	0000
	ISTOP=1	009630	0000
	WRITE(LO,2155) NREACH	009640	0000
853	CONTINUE	009650	0000
C	-----	009660	0000
C	CHECK IF WORK DAYS PER WEEK IN PROPER RANGE	009670	0000
	IF(DAYS.GE.4..AND.DAYS.LE.7..OR.DAYS.EQ.0.) GO TO 854	009680	0000
	ISTOP=1	009690	0000
	WRITE(LO,2160) NREACH	009700	0000
854	CONTINUE	009710	0000
C	IS THIS AN UNDERGROUND HEADING RATHER THAN CUT AND COVER	009730	0000
	IF(ISHAPE.GT.0) GO TO 858	009740	0000
C	-----	009750	0000
C	CHECK FOR INPUT VALUES FOR BOX WIDTH AND HEIGHT	009760	0000
	IF(BFBWDT.GT.0.0.AND.BFBHT.GT.0.0) GO TO 855	009770	0000
	ISTOP=1	009780	0000
	WRITE(LO,2165) NREACH	009790	0000
855	CONTINUE	009800	0000
C	-----	009810	0000
C	CHECK IF TOTAL CLEAR BOX WIDTH EXCEEDS 40 FEET	009820	0000
	IF(BFBWDT.GT.40.) WRITE(LO,2170) NREACH	009830	0000
C	-----	009840	0000
C	CHECK TYPE OF BOX SECTION	009850	0000
	IF(ibox2.EQ.1) GO TO 857	009860	0000
C	-----	009870	0000
C	SINGLE LEVEL BOX -- CHECK IF NUMBER OF BOX UNITS IS SPECIFIED	009880	0000
	IF(NBOX.GT.0) GO TO 856	009890	0000
	ISTOP=1	009900	0000
	WRITE(LO,2175) NREACH	009910	0000
856	CONTINUE	009920	0000
C	-----	009930	0000
C	CHECK IF BOX HEIGHT IS GREATER THAN 20 FEET	009940	0000
	IF(BFBHT.GT.20.) WRITE(LO,2180) NREACH	009950	0000
	GO TO 858	009960	0000
C	-----	009970	0000
C	DOUBLE LEVEL BOX -- TWO UNITS HIGH AND TWO UNITS WIDE	009980	0000
C	CHECK IF TOTAL CLEAR BOX HEIGHT EXCEEDS 40 FEET	009990	0000
857	IF(BFBHT.GT.40.) WRITE(LO,2185) NREACH	010000	0000
858	CONTINUE	010010	0000
C	-----	010020	0000
	TRDATA(NREACH,1)=NSHAFT	010030	0000
	TRDATA(NREACH,2)=BFT	010040	0000
	TRDATA(NREACH,3)=ISHAPE	010050	0000
	TRDATA(NREACH,4)=MTM	010060	0000
	TRDATA(NREACH,8)=HOURS	010070	0000
	TRDATA(NREACH,9)=DAYS	010080	0000
	TRDATA(NREACH,10)=NBOX	010090	0000
	TRDATA(NREACH,11)=BFBWDT	010100	0000
	TRDATA(NREACH,12)=BFBHT	010110	0000
	TRDATA(NREACH,13)=IBOX2	010120	0000
	GO TO 81	010130	0000

(Continued)

COSTUN Listing (Continued)

C	-----	010140	0000
C	END OF REACH INPUT	010150	0000
C	865 CONTINUE	010160	0000
C	-----	010170	0000
C	CHECK REACH AND SEGMENT INFORMATION FOR COMPATABILITY	010180	0000
C	-----	010190	0000
	DO 87 I=1,NTS	010200	0000
	NREACH=A(I,4)	010210	0000
	NTSEG=A(I,1)	010220	0000
	NTSTYP=A(I,16)	010230	0000
	MEX=A(I,7)	010240	0000
	BFT=TRDATA(NREACH,2)	010250	0000
	ISHAPE=TRDATA(NREACH,3)	010260	0000
	MTM=TRDATA(NREACH,4)	010270	0000
	ISUPPT=A(I,26)	010280	0000
	MSTAB=A(I,31)	010290	0000
	MUST=A(I,32)	010300	0000
	NPL=A(I,2)	010310	0000
	NPR=A(I,3)	010320	0000
	ELNPL=CNP(NPL,2)	010330	0000
	ELNPR=CNP(NPR,2)	010340	0000
	ELAUG=(ELNPL+ELNPR)/2.	010350	0000
	ELWATR=A(I,14)	010360	0000
	ELIMP=A(I,24)	010370	0000
C	IF THE TUNNEL SEGMENT IS MOLED, ITS SHAPE MUST BE CIRCULAR	010380	0000
	IF(MEX.NE.2.AND.MEX.NE.3) GO TO 860	010390	0000
	IF(ISHAPE.EQ.1) GO TO 860	010400	0000
	WRITE(LO,1040) NTSEG,NREACH	010410	0000
	ISTOP=1	010420	0000
C	860 CONTINUE	010430	0000
C	-----	010440	0000
C	CHECK FOR CUT AND COVER OR ROCK TUNNEL	010450	0000
C	IF(NTSTYP.NE.2) GO TO 865	010460	0000
C	-----	010470	0000
C	CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT	010480	0000
	IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 861	010490	0000
	IWATER=A(I,23)	010500	0000
	D10=A(I,19)	010510	0000
	PERM=A(I,25)	010520	0000
	IF(IWATER.EQ.0.OR.PERM.LT.10.E-10.AND.D10.LE.0.08.OR.PERM.GT.	010530	0000
	110.E-10.AND.PERM.LE.0.0006) GO TO 861	010540	0000
C	CHECK IF IMPERVIOUS LAYER IS ABOVE TUNNEL WHEN DEWATERING MAY	010550	0000
C	BE USED AS A STABILIZATION METHOD	010560	0000
	IF(ELIMP.LT.ELAUG+BFT/2.) GO TO 861	010570	0000
	WRITE(LO,2190) NTSEG,NREACH	010580	0000
	A(I,24)=ELAUG-BFT/2.	010590	0000
C	861 CONTINUE	010600	0000
C	-----	010610	0000
C	CHECK IF TRUCK TRANSPORT IS SPECIFIED AND COMPRESSED AIR REQUIRED	010620	0000
	IF(MTM.NE.1.OR.MSTAB.GT.1.OR.MSTAB.EQ.0.OR.MUST.LT.4) GO TO 863	010630	0000
	ISTOP=1	010640	0000
	WRITE(LO,2195) NTSEG,NREACH	010650	0000
C	863 CONTINUE	010660	0000
C	-----	010670	0000
C	CAST IRON TUNNEL SUPPORT - CIRCULAR TUNNELS ONLY	010680	0000
	IF(ISUPPT.GT.1.OR.ISHAPE.EQ.1) GO TO 865	010690	0000
	ISTOP=1	010700	0000
	WRITE(LO,2200) NTSEG,NREACH	010710	0000

(Continued)

COSTUN Listing (Continued)

865	CONTINUE	010720	0000
C	-----	010730	0000
C	CHECK IF SHAPE CODE AGREES WITH TUNNEL TYPE	010740	0000
	IF(NTSTYP.LT.3.AND.ISHAPE.GT.0) GO TO 867	010750	0000
	IF(NTSTYP.EQ.3.AND.ISHAPE.EQ.0) GO TO 867	010760	0000
	ISTOP=1	010770	0000
	IF(NTSTYP.LT.3) WRITE(LO,2201) NTSEG,NREACH	010780	0000
	IF(NTSTYP.EQ.3) WRITE(LO,2202) NTSEG,NREACH	010790	0000
C	-----	010800	0000
C	CHECK FOR CUT AND COVER EXCAVATION	010810	0000
867	IF(NTSTYP.NE.3) GO TO 87	010820	0000
	BFBHT=TRDATA(NREACH,13)	010830	0000
C	-----	010840	0000
C	CHECK IF SOUND ROCK LINE IS ABOVE BASE OF TRENCH AND RQD IS LESS	010850	0000
C	THAN 50	010860	0000
	RQD=A(I,6)	010865	0000
	ELROCK=A(I,27)	010870	0000
	IF(RQD.GE.50..OR.ELROCK.LT.ELAUG-BFBHT/2.) GO TO 869	010880	0000
	IF(RQD.GE.25.) WRITE(LO,2203) NTSEG,NREACH	010890	0000
	IF(RQD.GE.25.) GO TO 869	010900	0000
	ISTOP=1	010910	0000
	WRITE(LO,2204) NTSEG,NREACH	010920	0000
869	CONTINUE	010930	0000
C	-----	010940	0000
C	CHECK FOR WATER TABLE ABOVE BASE OF TRENCH AND ABOVE IMPERVIOUS	010950	0000
C	LAYER FOR SLOPING CUT EXCAVATION -- IWATER MUST EQUAL 1	010960	0000
	IF(MEX.NE.7) GO TO 87	010970	0000
	IWATER=A(I,23)	010980	0000
	IF(IWATER.EQ.1) GO TO 87	010990	0000
	IF(ELWATR.LT.ELAUG-BFBHT/2..OR.ELWATR.LE.ELIMP) GO TO 87	011000	0000
	ISTOP=1	011010	0000
	WRITE(LO,2205) NTSEG,NREACH	011020	0000
C	-----	011030	0000
87	CONTINUE	011040	0000
C	-----	011050	0000
C	*****	011060	0000
C	-----	011070	0000
C	READ SHAFT SEGMENT DATA *****	011080	0000
C	-----	011090	0000
C	INITIALIZE SHAFT SEGMENT ARRAY	011100	0000
	DO 88 I=1,NSSMAX	011110	0000
88	B(I,1)=-10.E30	011120	0000
C	INITIALIZE THE SHAFT ARRAY	011130	0000
	DO 89 I=1,NSSMAX	011140	0000
89	SHAFT(I,1)=-10.E30	011150	0000
	IPS=0	011160	0000
	I=0	011170	0000
90	I=I+1	011180	0000
C	-----	011190	0000
C	-----	011200	0000
C	CHECK FOR MAX NUMBER OF SHAFT SEGMENTS	011210	0000
	IF(I.LE.NSSMAX) GO TO 95	011220	0000
C	-----	011230	0000
C	CHECK FOR END OF SHAFT SEGMENT DATA. NDUM=DUMMY SEGMENT NUMBER	011240	0000
91	READ(LI,1020) NDUM	011250	0000
	IF(NDUM.EQ.9999) GO TO 130	011260	0000
	WRITE(LO,1017) NSSMAX	011270	0000
	ISTOP=1	011280	0000

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COSTUN Listing (Continued)

C	GO TO 91	011290 0000
C	-----	011300 0000
C	READ SHAFT SEGMENT DATA FROM CARD	011310 0000
C	95 READ(LI,1007) (B(I,J),J=1,15)	011320 0000
	NSHAFT=B(I,1)	011330 0000
	NSSEG=B(I,2)	011340 0000
	NSSTYP=B(I,15)	011350 0000
C	-----	011360 0000
C	CHECK FOR LAST SHAFT CARD	011370 0000
	IF(NSHAFT.EQ.9999) GO TO 130	011380 0000
	IF(NSHAFT.LE.NSMAX.AND.NSHAFT.GT.0) GO TO 100	011390 0000
	WRITE(LO,1034) NSHAFT,NSSEG,NSMAX	011400 0000
	ISTOP=1	011410 0000
100	CONTINUE	011420 0000
C	-----	011430 0000
C	CHECK FOR MISSING SEPARATOR CARD	011440 0000
	IF(NSSTYP.NE.0) GO TO 101	011450 0000
	ISTOP=1	011460 0000
	WRITE(LO,1503)	011470 0000
101	CONTINUE	011480 0000
C	-----	011490 0000
C	CHECK FOR PROPER SHAFT TYPE CODE	011500 0000
	IF(NSSTYP.GE.1.AND.NSSTYP.LE.3) GO TO 102	011510 0000
	ISTOP=1	011520 0000
	WRITE(LO,2207) NSSEG,NSHAFT	011530 0000
	GO TO 425	011540 0000
102	CONTINUE	011550 0000
C	-----	011560 0000
C	READ SECOND SEGMENT DATA CARD IF NOT ROCK TUNNEL	011570 0000
	IF(NSSTYP.GT.1) READ(LI,1008) (B(I,J),J=16,27)	011580 0000
		011590 0000
C	-----	011600 0000
C	CHECK FOR PREVIOUS USE OF SHAFT NUMBER	011610 0000
	IF(I.EQ.1) GO TO 105	011620 0000
	IF(NSHAFT.EQ.IPS) GO TO 106	011630 0000
	IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 105	011640 0000
	WRITE(LO,1023) NSSEG,NSHAFT	011650 0000
	ISTOP=1	011660 0000
105	SHAFT(NSHAFT,1)=0.	011670 0000
106	CONTINUE	011680 0000
C	-----	011690 0000
C	CHECK THAT SHAFT SEGMENT CARDS HAVE BEEN PROPERLY ARRANGED	011700 0000
	IF(I.EQ.1) GO TO 108	011710 0000
	IF(IPS.NE.NSHAFT) GO TO 108	011720 0000
	IF(B(I,3).EQ.B(I-1,4)) GO TO 108	011730 0000
	WRITE(LO,1115) NSSEG,NSHAFT	011740 0000
	ISTOP=1	011750 0000
108	CONTINUE	011760 0000
C	-----	011770 0000
C	CHECK THAT ALL SHAFT NODAL POINTS HAVE BEEN INPUT	011780 0000
	NPT=B(I,3)	011790 0000
	NPB=B(I,4)	011800 0000
	ELNPT=CNP(NPT,2)	011810 0000
	ELNPB=CNP(NPB,2)	011820 0000
	IF(ELNPT.GT.-10.E29.AND.ELNPB.GT.-10.E29) GO TO 110	011830 0000
	WRITE(LO,1131) NSSEG,NSHAFT	011840 0000
	ISTOP=1	011850 0000
110	CONTINUE	011860 0000

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COSTUN Listing (Continued)

C	-----	011970	0000
C	CHECK FOR SHAFT BEING A PORTAL. IF SO, RECCRD THIS FACT	011980	0000
	NPORT=0	011990	0000
	IF(NPT.EQ.NPB) NPORT=1	011990	0000
	SHAFT(NSHAFT,23)=NPORT	011990	0000
C	IF SHAFT IS A PORTAL, SKIP THE FOLLOWING INPUT CHECKS	011990	0000
	IF(NPT.EQ.NPB) GO TO 128	011990	0000
C	-----	011990	0000
C	CHECK FOR PROPER EXCAVATION METHOD	011990	0000
	MEX=B(I,7)	011990	0000
	IF(MEX.GE.0.AND.MEX.LE.4) GO TO 112	011990	0000
	ISTOP=1	011990	0000
	WRITE(LO,1029) NSSEG,NSHAFT	011990	0000
112	CONTINUE	012000	0000
C	-----	012010	0000
C	CHECK FOR DUMMY SHAFT AND BYPASS FURTHER CHECKS	012020	0000
	LINING=B(I,10)	012030	0000
	RS=B(I,5)	012040	0000
	RQD=B(I,6)	012050	0000
	IF(NSSTYP.EQ.1.AND.RS.LE.0.AND.RQD.LE.0.	012060	0000
	1.AND.MEX.EQ.0.AND.LINING.EQ.0) GO TO 129	012070	0000
113	CONTINUE	012080	0000
C	-----	012090	0000
C	CHECK FOR PROPER EXCAVATION METHOD FOR SHAFT TYPE SPECIFIED	012100	0000
	IF(NSSTYP.EQ.1.AND.MEX.LT.1.OR.NSSTYP.EQ.1.AND.MEX.GT.2) GO TO 114	012110	0000
	IF(NSSTYP.EQ.2.AND.MEX.LT.3) GO TO 114	012120	0000
	IF(NSSTYP.EQ.3.AND.MEX.GT.0) GO TO 114	012130	0000
	GO TO 115	012140	0000
114	ISTOP=1	012150	0000
	WRITE(LO,2210) NSSEG,NSHAFT	012160	0000
C	-----	012170	0000
C	CHECK FOR ADVANCE RATE NOT SPECIFIED	012180	0000
115	AR=B(I,8)	012190	0000
	IF(AR.EQ.0.0) GO TO 120	012200	0000
C	-----	012210	0000
C	CHECK FOR ADVANCE RATE LESS THAN 0 FT/DAY	012220	0000
	IF(AR.GT.0.0) GO TO 120	012230	0000
	ISTOP=1	012240	0000
	WRITE(LO,1075) NSSEG,NSHAFT	012250	0000
C	-----	012260	0000
C	CHECK FOR ROCK STRENGTH GREATER THAN 500 PSI	012270	0000
120	CONTINUE	012280	0000
	IF(RS.LT.500.AND.NSSTYP.EQ.1) WRITE(LO,1070) NSSEG,NSHAFT	012290	0000
C	-----	012300	0000
C	CHECK FOR PROPER SHAFT CODE IF RQD IS LESS THAN 25.	012310	0000
	IF(NSSTYP.GT.1.OR.RQD.GE.25.) GO TO 122	012320	0000
	ISTOP=1	012330	0000
	WRITE(LO,2212) NSSEG,NSHAFT	012340	0000
122	CONTINUE	012350	0000
C	-----	012360	0000
C	IS SHAFT IN SOFT GROUND AND RQD GREATER THAN 25.	012370	0000
	IF(NSSTYP.EQ.2.AND.RQD.GT.25.) WRITE(LO,2215) NSSEG,NSHAFT	012380	0000
C	-----	012390	0000
C	CHECK FOR RQD BETWEEN 0 AND 100.	012400	0000
	IF(RQD.GE.0.0.AND.RQD.LE.100.) GO TO 126	012410	0000
	WRITE(LO,1072) NSSEG,NSHAFT	012420	0000
	ISTOP=1	012430	0000
126	CONTINUE	012440	0000

(Continued)

COSTUN Listing (Continued)

C	-----	012450	0000
C	CHECK FOR CONTRADICTION OF SPECIFYING A THICKNESS FOR NO LINING	012460	0000
	LINING=B(I,10)	012470	0000
	IF(LINING.NE.0.OR.NSSTYP.NE.1) GO TO 127	012480	0000
	TL=B(I,11)	012490	0000
	IF(TL.LE.0.001) GO TO 127	012500	0000
	WRITE(LO,1046) NSSEG,NSHAFT	012510	0000
	ISTOP=1	012520	0000
127	CONTINUE	012530	0000
C	-----	012540	0000
C	CHECK FOR PROPER LINING TYPE CODE	012550	0000
	IF(LINING.GE.0.AND.LINING.LE.3) GO TO 1270	012560	0000
	WRITE(LO,1048) NSSEG,NSHAFT	012570	0000
	ISTOP=1	012580	0000
1270	CONTINUE	012590	0000
C	-----	012600	0000
C	CHECK FOR PROPER LINING CODE FOR SHAFT TYPE SPECIFIED	012610	0000
	IF(NSSTYP.LT.3.AND.LINING.NE.3.OR.NSSTYP.EQ.3.AND.LINING.EQ.3)	012620	0000
	GO TO 1272	012630	0000
	ISTOP=1	012640	0000
	WRITE(LO,2220) NSSEG,NSHAFT	012650	0000
C	-----	012660	0000
C	CHECK FOR PROPER WATERTIGHT CODE	012670	0000
1272	LINWT=B(I,14)	012680	0000
	IF(LINWT.EQ.0.OR.LINWT.EQ.1) GO TO 1274	012690	0000
	ISTOP=1	012700	0000
	WRITE(LO,2225) NSSEG,NSHAFT	012710	0000
1274	CONTINUE	012720	0000
C	-----	012730	0000
C	ALL CUT AND COVER BOX SEGMENTS ARE DESIGNED AS WATERTIGHT -	012740	0000
C	INPUT IGNORED	012750	0000
C	IF(NSSTYP.EQ.3.AND.LINWT.EQ.0) WRITE(LO,2227) NSSEG,NSHAFT	012760	0000
C	-----	012770	0000
C	A LINING OR SUPPORT MUST BE SPECIFIED WHEN WATERTIGHTNESS REQUIRED	012780	0000
	ISUPPT=B(I,22)	012790	0000
	IF(LINWT.EQ.0.OR.LINING.GT.0) GO TO 1276	012800	0000
	IF(NSSTYP.GT.1.AND.ISUPPT.LE.3) GO TO 1276	012810	0000
	ISTOP=1	012820	0000
	WRITE(LO,2230) NSSEG,NSHAFT	012830	0000
C	-----	012840	0000
C	CHECK IF GROUNDWATER ELEVATION NOT INPUT AND WATERTIGHT REQUIRED	012850	0000
1276	ELWATR=B(I,13)	012860	0000
	IF(LINWT.EQ.1.AND.ELWATR.EQ.0) WRITE(LO,2235) NSSEG,NSHAFT	012870	0000
C	-----	012880	0000
C	CHECK IF SHAFT NOT IN ROCK AND GROUNDWATER ELEV NOT SPECIFIED	012890	0000
	IF(NSSTYP.GT.1.AND.ELWATR.EQ.0) WRITE(LO,2235) NSSEG,NSHAFT	012900	0000
C	-----	012910	0000
C	CHECK IF GROUND WATER ELEVATION IS IN MIDDLE OF SHAFT SEGMENT	012920	0000
	IF(ELWATR.GE.ELNPT.OR.ELWATR.LE.ELNPB) GO TO 1277	012930	0000
	ISTOP=1	012940	0000
	WRITE(LO,2240) NSSEG,NSHAFT	012950	0000
C	-----	012960	0000
C	CHECK REMAINING DATA IF SHAFT IS NOT IN ROCK	012970	0000
1277	IF(NSSTYP.EQ.1) GO TO 128	012980	0000
C	-----	012990	0000
C	CHECK IF EFFECTIVE GRAIN SIZE IS INPUT	013000	0000
	D10=B(I,16)	013010	0000
	IF(D10.GT.0) GO TO 1278	013020	0000

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COSTUN Listing (Continued)

	ISTOP=1	013030 0000
	WRITE(LO,2245) NSSEG,NSHAFT	013040 0000
C	-----	013050 0000
	CHECK THAT PHI AND/OR COHESION ARE SPECIFIED	013060 0000
1278	PHI=B(I,19)	013070 0000
	COHESN=B(I,17)	013080 0000
	IF(PHI.GT.0..OR.COHESN.GT.0.) GO TO 1279	013090 0000
	ISTOP=1	013100 0000
	WRITE(LO,2250) NSSEG,NSHAFT	013110 0000
1279	CONTINUE	013120 0000
C	-----	013130 0000
	CHECK FOR POSSIBLE ERROR IN PERMEABILITY INPUT	013140 0000
C	PERM=B(I,23)	013150 0000
	IF(PERM.GT.10.) WRITE(LO,2251) NSSEG,NSHAFT	013160 0000
C	-----	013170 0000
C	CHECK IF PHI GREATER THAN 45 - WARNING, OR GREATER THAN 100 -ERROR	013180 0000
	IF(PHI.GT.45.) WRITE(LO,2252) NSSEG,NSHAFT	013190 0000
	IF(PHI.LT.100.) GO TO 1280	013200 0000
	ISTOP=1	013210 0000
	WRITE(LO,2253) NSSEG,NSHAFT	013220 0000
C	-----	013230 0000
	CHECK IF GAMMA GREATER THAN 200.	013240 0000
1280	GAMMA=B(I,18)	013250 0000
	IF(GAMMA.LE.200.) GO TO 1281	013260 0000
	ISTOP=1	013270 0000
	WRITE(LO,2254) NSSEG,NSHAFT	013280 0000
C	-----	013290 0000
C	CHECK FOR PROPER DEWATERING CODE	013300 0000
1281	IWATER=B(I,21)	013310 0000
	IF(IWATER.EQ.0.OR.IWATER.EQ.1) GO TO 1282	013320 0000
	ISTOP=1	013330 0000
	WRITE(LO,2255) NSSEG,NSHAFT	013340 0000
C	-----	013350 0000
	CHECK IF IMPERVIOUS LAYER IS A REQUIRED INPUT	013360 0000
1282	MSTAB=B(I,25)	013370 0000
	MUST=B(I,26)	013380 0000
	IF(MUST.GE.3.AND.MSTAB.NE.2) GO TO 1284	013390 0000
	IF(IWATER.EQ.0.OR.PERM.LT.10.E-10.AND.D10.LE.0.08.OR.PERM.GT.	013400 0000
	110.E-10.AND.PERM.LE.0.0006) GO TO 1284	013410 0000
C	-----	013420 0000
C	DEWATERING IS ALLOWED. CHECK IF IMPERVIOUS LAYER IS NOT	013430 0000
C	SPECIFIED OR IF THE IMPERVIOUS LAYER IS ABOVE BASE OF SEGMENT.	013440 0000
	ELIMP=B(I,20)	013450 0000
	IF(ELIMP.EQ.0.0) WRITE(LO,2260) NSSEG,NSHAFT	013460 0000
	IF(ELIMP.LE.ELNPB) GO TO 1284	013470 0000
	ISTOP=1	013480 0000
	WRITE(LO,2262) NSSEG,NSHAFT	013490 0000
1284	CONTINUE	013500 0000
C	-----	013510 0000
C	CHECK FOR PROPER SUPPORT CODE	013520 0000
	IF(ISUPPT.GE.1.AND.ISUPPT.LE.5) GO TO 1285	013530 0000
	ISTOP=1	013540 0000
	WRITE(LO,2265) NSSEG,NSHAFT	013550 0000
1285	CONTINUE	013560 0000
C	-----	013570 0000
C	CHECK FOR PROPER SUPPORT CODE FOR SHAFT TYPE SPECIFIED	013580 0000
	IF(NSSTYP.EQ.2.AND.ISUPPT.GT.0.OR.NSSTYP.EQ.3.AND.ISUPPT.EQ.5)	013590 0000
	GO TO 1286	013600 0000

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COSTUN Listing (Continued)

	ISTOP=1	013610 0000
	WRITE(LO,2270) NSSEG,NSHAFT	013620 0000
1286	CONTINUE	013630 0000
C	-----	013640 0000
C	CHECK FOR PROPER LINING CODE FOR SUPPORT TYPE SPECIFIED	013650 0000
	IF(ISUPPT.LE.3.AND.LINING.EQ.0) GO TO 1288	013660 0000
	IF(ISUPPT.EQ.5.AND.LINING.EQ.3) GO TO 1288	013670 0000
	IF(ISUPPT.EQ.4.AND.LINING.EQ.0) GO TO 1287	013680 0000
	IF(ISUPPT.EQ.4.AND.LINING.NE.3) GO TO 1288	013690 0000
1287	ISTOP=1	013700 0000
	WRITE(LO,2275) NSSEG,NSHAFT	013710 0000
1288	CONTINUE	013720 0000
C	-----	013730 0000
C	CHECK FOR CUT AND COVER SHAFT	013740 0000
	IF(NSSTYP.EQ.3) GO TO 129	013750 0000
C	-----	013760 0000
C	CHECK FOR HIGH STABILITY NUMBER - MAY RESULT IN UNEXCAVATABLE JOB	013770 0000
	STABNO=B(I,24)	013780 0000
	IF(STABNO.LE.9.AND.PHI.LT.29.OR.STABNO.LE.7.AND.PHI.GE.29)	013790 0000
	1 GO TO 1289	013800 0000
	ISTOP=1	013810 0000
	WRITE(LO,2285) NSSEG,NSHAFT	013820 0000
C	-----	013830 0000
C	CHECK FOR PROPER STABILIZATION CODE	013840 0000
1289	MSTAB=B(I,25)	013850 0000
	IF(MSTAB.GE.0.AND.MSTAB.LE.3) GO TO 1290	013860 0000
	ISTOP=1	013870 0000
	WRITE(LO,2290) NSSEG,NSHAFT	013880 0000
C	-----	013890 0000
C	CHECK FOR PROPER USE OF STABILIZATION METHOD CODE	013900 0000
1290	MUST=B(I,26)	013910 0000
	IF(MUST.GE.1.AND.MUST.LE.4) GO TO 1292	013920 0000
	ISTOP=1	013930 0000
	WRITE(LO,2295) NSSEG,NSHAFT	013940 0000
C	-----	013950 0000
C	CHECK FOR AIR PRESSURE INPUT IF STABILITY NUMBER INPUT AND	013960 0000
C	AIR PRESSURE STABILIZATION INPUT	013970 0000
1292	AIRPR=B(I,27)	013980 0000
	IF(STABNO.GT.0.0.AND.MSTAB.EQ.1.AND.AIRPR.EQ.0.0) GO TO 1293	013990 0000
	GO TO 1294	014000 0000
1293	ISTOP=1	014010 0000
	WRITE(LO,2300) NSSEG,NSHAFT	014020 0000
1294	CONTINUE	014030 0000
C	-----	014040 0000
C	CHECK FOR USE CODE=4 WHEN STABILITY NUMBER IS SPECIFIED	014050 0000
	IF(STABNO.EQ.0.OR.MUST.EQ.4) GO TO 1296	014060 0000
	ISTOP=1	014070 0000
	WRITE(LO,2305) NSSEG,NSHAFT	014080 0000
1296	CONTINUE	014090 0000
C	-----	014100 0000
C	CHECK IF STABILIZATION METHOD NOT COMPRESSED AIR BUT AIRPR GT 0	014110 0000
	IF(MSTAB.EQ.1.OR.AIRPR.EQ.0.) GO TO 1297	014120 0000
	ISTOP=1	014130 0000
	WRITE(LO,2307) NSSEG,NSHAFT	014140 0000
1297	CONTINUE	014150 0000
C	-----	014160 0000
C	CHECK IF STABILIZATION METHOD AGREES WITH USE CODE	014170 0000
	IF(MSTAB.GE.0.AND.MUST.GT.2.OR.MSTAB.EQ.0.AND.MUST.LT.3)GO TO 1298	014180 0000

(Continued)

COSTUN Listing (Continued)

	ISTOP=1	014190 0000
	WRITE(LO,2310) NSSEG,NSHAFT	014200 0000
1298	CONTINUE	014210 0000
C	-----	014220 0000
C	CHECK IF STABILIZATION METHOD IS INPUT	014230 0000
C	IF(MSTAB.EQ.0) GO TO 128	014240 0000
C	-----	014250 0000
C	CHECK IF STABILIZATION METHOD IS ACCEPTABLE	014260 0000
C	GO TO (1300,1302,1304), MSTAB	014270 0000
C	-----	014280 0000
C	AIR PRESSURE -- CHECK IF SOIL IS A GRAVEL	014290 0000
1300	IF(PERM.LT.10.E-10.AND.D10.GT.2.) GO TO 1305	014300 0000
C	IF(PERM.GT.0.4) GO TO 1305	014310 0000
C	CHECK IF SOIL IS A CLAY	014320 0000
C	IF(D10.LE.0.005) GO TO 1308	014330 0000
C	CHECK IF SHAFT SEGMENT ABOVE WATER TABLE	014340 0000
C	IF(ELWATR.LE.ELNPB) GO TO 1308	014350 0000
C	CHECK IF WATER HEAD LESS THAN 115 FEET	014360 0000
	ELAUG=(ELNPT+ELNPB)/2.	014370 0000
	IF(ELWATR-ELAUG.LE.115.) GO TO 1308	014380 0000
	GO TO 1305	014390 0000
C	-----	014400 0000
C	DEWATERING -- CHECK IF DEWATERING IS ALLOWED	014410 0000
1302	IF(IWATER.EQ.0) GO TO 1305	014420 0000
C	CHECK IF SHAFT SEGMENT ABOVE WATER TABLE	014430 0000
C	IF(ELWATR.LE.ELNPB) GO TO 1305	014440 0000
C	CHECK IF SOIL IS FINE SAND OR COARSER OR IS REASONABLY PERMEABLE	014450 0000
	IF(PERM.LT.10.E-10.AND.D10.GT.0.08) GO TO 1308	014460 0000
	IF(PERM.GT.0.0006) GO TO 1308	014470 0000
	GO TO 1305	014480 0000
C	-----	014490 0000
C	GROUND INJECTIONS -- CHECK IF SOIL IS NOT CLAY	014500 0000
1304	IF(D10.GT.0.005) GO TO 1308	014510 0000
C	-----	014520 0000
C	STABILIZATION METHOD IS NOT ACCEPTABLE	014530 0000
1305	MSTAC=2	014540 0000
C	CHECK IF USE CODE =4	014550 0000
	IF(MUST.EQ.4) GO TO 1306	014560 0000
	WRITE(LO,2315) NSSEG,NSHAFT	014570 0000
	GO TO 1310	014580 0000
1306	ISTOP=1	014590 0000
	WRITE(LO,2320) NSSEG,NSHAFT	014600 0000
	GO TO 1310	014610 0000
C	-----	014620 0000
C	STABILIZATION METHOD IS ACCEPTABLE	014630 0000
1308	MSTAC=1	014640 0000
1310	B(I,28)=MSTAC	014650 0000
C	-----	014660 0000
C	CHECK FOR CORRECT GROUNDWATER CODE	014670 0000
128	INFLOW=B(I,9)	014680 0000
	IF(INFLOW.EQ.0.OR.INFLOW.EQ.1) GO TO 129	014690 0000
	WRITE(LO,1047) NSSEG,NSHAFT	014700 0000
	ISTOP=1	014710 0000
C	-----	014720 0000
129	IPS=NSHAFT	014730 0000
	GO TO 90	014740 0000
C	END OF SHAFT SEGMENT DATA	014750 0000
130	CONTINUE	014760 0000

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COSTUN Listing (Continued)

C	*****	014770	0000
C	NSS=I-1	014780	0000
C	*****	014790	0000
C	*****	014800	0000
C	*****	014810	0000
C	*****	014820	0000
C	*****	014830	0000
C	*****	014840	0000
C	*****	014850	0000
C	*****	014860	0000
C	*****	014870	0000
C	*****	014880	0000
C	*****	014890	0000
C	*****	014900	0000
C	*****	014910	0000
C	*****	014920	0000
C	*****	014930	0000
C	*****	014940	0000
C	*****	014950	0000
C	*****	014960	0000
C	*****	014970	0000
C	*****	014980	0000
C	*****	014990	0000
C	*****	015000	0000
C	*****	015010	0000
C	*****	015020	0000
C	*****	015030	0000
C	*****	015040	0000
C	*****	015050	0000
C	*****	015060	0000
C	*****	015070	0000
C	*****	015080	0000
C	*****	015090	0000
C	*****	015100	0000
C	*****	015110	0000
C	*****	015120	0000
C	*****	015130	0000
C	*****	015140	0000
C	*****	015150	0000
C	*****	015160	0000
C	*****	015170	0000
C	*****	015180	0000
C	*****	015190	0000
C	*****	015200	0000
C	*****	015210	0000
C	*****	015220	0000
C	*****	015230	0000
C	*****	015240	0000
C	*****	015250	0000
C	*****	015260	0000
C	*****	015270	0000
C	*****	015280	0000
C	*****	015290	0000
C	*****	015300	0000
C	*****	015310	0000
C	*****	015320	0000
C	*****	015330	0000
C	*****	015340	0000

(Continued)

COSTUN Listing (Continued)

	IF(HOURS.GE.0..AND.HOURS.LE.24.) GO TO 137	015350 0000
	ISTOP=1	015360 0000
	WRITE(LO,2335) NSHAFT	015370 0000
137	CONTINUE	015380 0000
C	-----	015390 0000
C	CHECK IF WORK DAYS PER WEEK IN PROPER RANGE	015400 0000
	IF(DAYS.GE.4..AND.DAYS.LE.7..OR.DAYS.EQ.0.) GO TO 138	015410 0000
	ISTOP=1	015420 0000
	WRITE(LO,2340) NSHAFT	015430 0000
138	CONTINUE	015440 0000
C	-----	015450 0000
	SHAFT(NSHAFT,1)=0.	015460 0000
	GO TO 131	015470 0000
C	END OF SHAFT PROPERTIES DATA	015480 0000
139	CONTINUE	015490 0000
C	*****	015500 0000
C	-----	015510 0000
C	-----	015520 0000
C	MAKE SURE THAT ALL TUNNEL SEGMENTS HAVE REACHES DEFINED FOR THEM	015530 0000
	DO 200 I=1,NTS	015540 0000
	NTSEG=A(I,1)	015550 0000
	NREACH=A(I,4)	015560 0000
	IF(TRDATA(NREACH,1).GT.0.) GO TO 200	015570 0000
	ISTOP=1	015580 0000
	WRITE(LO,1200) NTSEG,NREACH	015590 0000
200	CONTINUE	015600 0000
C	-----	015610 0000
C	CHECK THAT EVERY REACH NUMBER ASSIGNED HAS AT LEAST ONE TUNNEL	015620 0000
C	SEGMENT REFERRING TO IT	015630 0000
	DO 250 I=1,NTRMAX	015640 0000
	IF(TRDATA(I,1).LT.-10.E29) GO TO 250	015650 0000
	NREACH=I	015660 0000
	JJ=0	015670 0000
	DO 225 J=1,NTS	015680 0000
	IF(NREACH.EQ.A(J,4)) JJ=1	015690 0000
225	CONTINUE	015700 0000
	IF(JJ.EQ.1) GO TO 250	015710 0000
	ISTOP=1	015720 0000
	WRITE(LO,1203) NREACH	015730 0000
250	CONTINUE	015740 0000
C	-----	015750 0000
C	CHECK TO MAKE SURE ALL SHAFT SEGMENTS HAVE SHAFTS DEFINED FOR THEM	015760 0000
	DO 300 I=1,NSS	015770 0000
	NSSEG=B(I,2)	015780 0000
	NSHAFT=B(I,1)	015790 0000
	IF(SHAFT(NSHAFT,7).GT.-10.E29) GO TO 260	015800 0000
	ISTOP=1	015810 0000
	WRITE(LO,1201) NSSEG,NSHAFT	015820 0000
260	CONTINUE	015830 0000
C	-----	015840 0000
C	CHECK FOR PORTAL OR DUMMY SHAFT	015850 0000
	NPORT=SHAFT(NSHAFT,23)	015860 0000
	ISHAPS=SHAFT(NSHAFT,16)	015870 0000
	IF(NPORT.EQ.1.OR.ISHAPS.EQ.0) GO TO 300	015880 0000
C	-----	015890 0000
C	CHECK IF SHAPE CODE AGREES WITH SHAFT TYPE	015900 0000
	NSSTYP=B(I,15)	015910 0000
		015920 0000

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COSTUN Listing (Continued)

	IF(NSSTYP.GT.1.OR.ISHAPS.LT.2) GO TO 270	015930 0000
	ISTOP=1	015940 0000
	WRITE(LO,2345) NSSEG,NSHAFT	015950 0000
270	CONTINUE	015960 0000
C	-----	015970 0000
C	CAST IRON SHAFT SUPPORT - CIRCULAR SHAFTS ONLY	015980 0000
	ISUPPT=B(I,22)	015990 0000
	IF(ISHAPS.EQ.1.OR.ISUPPT.NE.1.OR.NSSTYP.NE.2) GO TO 280	016000 0000
	ISTOP=1	016010 0000
	WRITE(LO,2350) NSSEG,NSHAFT	016020 0000
280	CONTINUE	016030 0000
C	-----	016040 0000
C	IF THE SHAFT SEGMENT IS MOLED, ITS SHAPE MUST BE CIRCULAR	016050 0000
	MEX=B(I,7)	016060 0000
	IF(MEX.NE.2.AND.MEX.NE.3) GO TO 300	016070 0000
	IF(ISHAPS.EQ.1) GO TO 300	016080 0000
	ISTOP=1	016090 0000
	WRITE(LO,2355) NSSEG,NSHAFT	016100 0000
300	CONTINUE	016110 0000
C	-----	016120 0000
C	CHECK THAT EVERY SHAFT NUMBER ASSIGNED HAS AT LEAST ONE SHAFT	016130 0000
C	SEGMENT REFERRING TO IT	016140 0000
	DO 350 I=1,NSMAX	016150 0000
	IF(SHAFT(I,1).LT.-10.E29) GO TO 350	016160 0000
	NSHAFT=I	016170 0000
	JJ=0	016180 0000
	DO 325 J=1,NS5	016190 0000
	IF(NSHAFT.EQ.B(J,1)) JJ=1	016200 0000
325	CONTINUE	016210 0000
	IF(JJ.EQ.1) GO TO 350	016220 0000
	ISTOP=1	016230 0000
	WRITE(LO,1204) NSHAFT	016240 0000
350	CONTINUE	016250 0000
C	-----	016260 0000
C	CHECK ALL REACHES TO MAKE SURE THAT THERE IS AN EXIT SHAFT DEFINED	016270 0000
	DO 400 I=1,NTRMAX	016280 0000
	IF(TRDATA(I,1).LT.-10.E29) GO TO 400	016290 0000
	NSHAFT=TRDATA(I,1)	016300 0000
	IF(SHAFT(NSHAFT,7).GT.-10.E29) GO TO 400	016310 0000
	ISTOP=1	016320 0000
	WRITE(LO,1202) I,NSHAFT	016330 0000
400	CONTINUE	016340 0000
C	-----	016350 0000
C	CHECK FOR ANY STOPS FOUND	016360 0000
C	CONTINUE	016370 0000
	IF(ISTOP.EQ.0) GO TO 500	016380 0000
C	FATAL ERRORS DETECTED WHICH MAY MAKE FURTHER CALCULATIONS	016390 0000
C	MEANINGLESS. TERMINATE RUN AND GO TO NEXT SYSTEM DATA DECK	016400 0000
	WRITE(LO,1011)	016410 0000
	CALL NEXSET(LO,LI)	016420 0000
	RETURN	016430 0000
450	WRITE (LO,1504)	016440 0000
	ISTOP = 1	016450 0000
	GO TO 425	016460 0000
C	IF NO FATAL ERRORS LIST NODAL POINT DATA IF REQUESTED	016470 0000
500	IF(LIST(1).EQ.1) RETURN	016480 0000
	WRITE(LO,1003)	016490 0000
		016500 0000

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COSTUN Listing (Continued)

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DO 600 I=1,NPMAX
600 IF(CNP(I,2).GT.-10.E29) WRITE(LO,1024) I,CNP(I,2)
RETURN
C
1000 FORMAT(1X,I4,5X,F10.0)
1001 FORMAT(///,FATAL ERROR, NODAL POINT',IS,' MUST BE CHANGED TO A
NUMBER IN THE RANGE FROM 1 TO ',I4)
1002 FORMAT(4I4,F5.0,I3,F7.0,F5.0,I3,F4.0,F7.0,2I3,F5.0)
1003 FORMAT(///,10X,25H NODAL POINT' ELEVATION'//)
1004 FORMAT(10X,I7,8X,F9.2)
1005 FORMAT(3F4.0,F8.0,F4.0,F7.0,F5.0,F3.0,F5.0,F7.0,F3.0,F6.0,F4.0,F2.
10,F6.0,F3.0,F5.0)
1006 FORMAT(4X,2F4.0,F8.0,F4.0,F7.0,F5.0,F3.0,F5.0,F7.0,F3.0,F6.0,F4.0,
1F2.0,F6.0,F2.0,F1.0,F5.0)
1007 FORMAT(4F4.0,8X,F8.0,F4.0,F3.0,F6.0,2F3.0,F6.0,F2.0,F6.0,F3.0,
1F5.0)
1008 FORMAT(16X,2F8.0,F4.0,F3.0,F6.0,2F3.0,F8.0,F6.0,F2.0,F1.0,F5.0)
1011 FORMAT(///,1X,131('X'),/25X,'PROGRAM STOPPED BECAUSE OF ERRORS :
IN SUBROUTINE INPUT'//1X,131(1H*))
1013 FORMAT(///,FATAL ERROR, NODAL POINT',IS,' IS INPUTED ON TWO SEP
ARATE NODAL POINT CARDS')
1015 FORMAT(///,FATAL ERROR, SEGMENT',IS,' IN REACH',IS,' IS OUT OF
SEQUENCE,CHECK DATA CARDS ARRANGEMENT OR FOR CORRECT NODAL POINT
25')
1016 FORMAT(///,FATAL ERROR, ALIGNMENT INCLUDES MORE THAN THE ',I4,'
1 TUNNEL SEGMENTS ALLOWED')
1017 FORMAT(///,FATAL ERROR, ALIGNMENT INCLUDES MORE THAN THE ',I4,'
1 SHAFT SEGMENTS ALLOWED')
1020 FORMAT(2I4,F6.0,2I3,F5.0,F4.0,I3,2F5.0,I3,25X,I5)
1021 FORMAT(///,FATAL ERROR, REACH NUMBER',IS,' SHOULD BE CHANGED TO
1 ONE IN THE RANGE OF 1 TO ',I5)
1022 FORMAT(///,FATAL ERROR, SEGMENT',IS,' REFERS TO REACH',IS,' BU
1T THIS REACH NUMBER HAS BEEN PREVIOUSLY ASSIGNED')
1023 FORMAT(///,FATAL ERROR, SEGMENT',IS,' REFERS TO SHAFT',IS,' BU
1T THIS SHAFT NUMBER HAS BEEN PREVIOUSLY ASSIGNED')
1025 FORMAT(I4,F6.0,I3,F8.0,F7.0,F4.0,4F6.0,F5.0,F4.0)
1026 FORMAT(///,FATAL ERROR, DATA FOR REACH',IS,' HAVE BEEN SUPPLIED
1 ON TWO SEPARATE REACH CARDS')
1027 FORMAT(///,FATAL ERROR, DATA FOR SHAFT',IS,' HAVE BEEN SUPPLIED
1 ON TWO SEPARATE SHAFT CARDS')
1029 FORMAT(///,FATAL ERROR, EXCAVATION METHOD IN SEGMENT',IS,' IN SH
1AFT',IS,' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK),1,2,3,4')
1030 FORMAT(///,FATAL ERROR, EXCAVATION METHOD IN SEGMENT',IS,' IN RE
1ACH',IS,' WAS NOT SPECIFIED BY USING CODE 1,2,3,4,5,6,OR 7')
1031 FORMAT(///,FATAL ERROR, ONE OR BOTH NODAL POINTS IN SEGMENT',IS,'
1 IN REACH',IS,' WERE NOT LISTED WITH OTHER NODAL POINT DATA CARD
25')
1034 FORMAT(///,FATAL ERROR, SHAFT',IS,' LISTED WITH SHAFT SEGMENT',
1IS,' IS NOT NUMBERED IN THE RANGE OF 1 TO ',I5)
1040 FORMAT(///,FATAL ERROR, CIRCULAR SHAPE WAS NOT SPECIFIED FOR MOL
1ED EXCAVATION IN SEGMENT',IS,' IN REACH',IS)
1041 FORMAT(///,FATAL ERROR, MUCK TRANSPORT METHOD IN REACH',IS,' WA
1S NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,3,OR 4')
1042 FORMAT(///,FATAL ERROR, TUNNEL SHAPE IN REACH',IS,' WAS NOT SPE
1CIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3')
1043 FORMAT(///,FATAL ERROR, LINING TYPE IN SEGMENT',IS,' IN REACH',IS
1,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK),1,2,OR 3')
016510 0000
016520 0000
016530 0000
016540 0000
016550 0000
016560 0000
016570 0000
016580 0000
016590 0000
016600 0000
016610 0000
016620 0000
016630 0000
016640 0000
016650 0000
016660 0000
016670 0000
016680 0000
016690 0000
016700 0000
016710 0000
016720 0000
016730 0000
016740 0000
016745
016750 0000
016760 0000
016770 0000
016780 0000
016790 0000
016800 0000
016810 0000
016820 0000
016830 0000
016840 0000
016850 0000
016860 0000
016870 0000
016880 0000
016890 0000
016900 0000
016910 0000
016920 0000
016930 0000
016940 0000
016950 0000
016960 0000
016970 0000
016980 0000
016990 0000
017000 0000
017010 0000
017020 0000
017030 0000
017040 0000
017050 0000
017060 0000
017070 0000

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COSTUN Listing (Continued)

1045	FORMAT(/, FATAL ERROR, A LINING THICKNESS IS SPECIFIED FOR SEG	017080	0000
	MENT 'I4,' IN REACH 'I4,' BUT NO LINING WAS SPECIFIED')	017090	0000
1046	FORMAT(/, FATAL ERROR, A LINING THICKNESS IS SPECIFIED FOR SEG	017100	0000
	MENT 'I4,' IN SHAFT 'I4,' BUT NO LINING WAS SPECIFIED')	017110	0000
1047	FORMAT(/, FATAL ERROR, GROUNDWATER INFLOW IN SEGMENT 'I5,' IN S	017120	0000
	HAFT 'I5,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK) OR 1')	017130	0000
1048	FORMAT(/, FATAL ERROR, LINING TYPE IN SEGMENT 'I5,' IN SHAFT 'I5	017140	0000
	1,' WAS NOT SPECIFIED WITH A CODE OF ZERO(OR BLANK), 1, 2, OR 3')	017150	0000
1055	FORMAT(/, FATAL ERROR, SHAFT 'I5,' IS NOT NUMBERED IN THE RANG	017160	0000
	1E OF 1 TO 'I5')	017170	0000
1060	FORMAT(/, **** WARNING **** ROCK STRENGTH IS LESS THAN 500 PSI	017180	0000
	1 IN SEGMENT 'I5,' IN REACH 'I5,' GETTING CLOSE TO SOFT GROUND',	017190	0000
	25X, 14(1HX))	017200	0000
1062	FORMAT(/, FATAL ERROR, RQD IN SEGMENT 'I5,' IN REACH 'I5,	017210	0000
	1,' IS NOT A NUMBER FROM 0 TO 100')	017220	0000
1064	FORMAT(/, **** WARNING **** TUNNEL SIZE IN REACH 'I5,' IS NOT	017230	0000
	1 WITHIN THE RANGE OF 10 TO 40 FEET, 5X, 41(1HX))	017240	0000
1065	FORMAT(/, FATAL ERROR, ADVANCE RATE IN SEGMENT 'I5,' IN REACH',	017250	0000
	1 I5,' IS LESS THAN 0 FT/DAY')	017260	0000
1070	FORMAT(/, **** WARNING **** ROCK STRENGTH IS LESS THAN 500 PSI	017270	0000
	1 IN SEGMENT 'I5,' IN SHAFT 'I5,' GETTING CLOSE TO SOFT GROUND',	017280	0000
	25X, 14(1HX))	017290	0000
1072	FORMAT(/, FATAL ERROR, RQD IN SEGMENT 'I5,' IN SHAFT 'I5,	017300	0000
	1,' IS NOT A NUMBER FROM 0 TO 100')	017310	0000
1074	FORMAT(/, **** WARNING **** SHAFT SIZE IN SHAFT 'I5,' IS NOT	017320	0000
	1 WITHIN THE RANGE OF 10 TO 40 FEET, 5X, 41(1HX))	017330	0000
1075	FORMAT(/, FATAL ERROR, ADVANCE RATE IN SEGMENT 'I5,' IN SHAFT',	017340	0000
	1 I5,' IS LESS THAN 0 FT/DAY')	017350	0000
1115	FORMAT(/, FATAL ERROR, SEGMENT 'I5,' IN SHAFT 'I5,' IS OUT OF	017360	0000
	1SEQUENCE, CHECK DATA CARDS ARRANGEMENT OR FOR CORRECT NODAL POINT	017370	0000
	25')	017375	
1131	FORMAT(/, FATAL ERROR, ONE OR BOTH NODAL POINTS IN SEGMENT 'I5,	017380	0000
	1,' IN SHAFT 'I5,' WERE NOT LISTED WITH OTHER NODAL POINT DATA CARD	017390	0000
	25')	017400	0000
1200	FORMAT(/, FATAL ERROR, TUNNEL SEGMENT 'I5,' REFERS TO REACH 'I5	017410	0000
	1,' BUT NO SUCH REACH HAS BEEN INPUTED')	017420	0000
1201	FORMAT(/, FATAL ERROR, SHAFT SEGMENT 'I5,' REFERS TO SHAFT 'I5	017430	0000
	1,' BUT NO SUCH SHAFT HAS BEEN INPUTED')	017440	0000
1202	FORMAT(/, FATAL ERROR, REACH 'I5,' REFERS TO EXIT SHAFT 'I5,	017450	0000
	1,' BUT NO SUCH SHAFT HAS BEEN INPUTED')	017460	0000
1203	FORMAT(/, FATAL ERROR, TUNNEL REACH 'I5,' HAS BEEN ASSIGNED, BU	017470	0000
	1T NO TUNNEL SEGMENTS REFER TO IT')	017480	0000
1204	FORMAT(/, FATAL ERROR, SHAFT 'I5,' HAS BEEN ASSIGNED, BUT NO SH	017490	0000
	1AFT SEGMENTS REFER TO IT')	017500	0000
1500	FORMAT(/, FATAL ERROR, NO SEPARATOR CARD AFTER NODAL POINT DATA')	017510	0000
1501	FORMAT(/, FATAL ERROR, NO SEPARATOR CARD AFTER TUNNEL SEGMENT D	017520	0000
	1ATA', 25X, -- OR --')	017530	0000
1502	FORMAT(/, FATAL ERROR, NO SEPARATOR CARD AFTER TUNNEL REACH DAT	017540	0000
	1A')	017550	0000
1503	FORMAT(/, FATAL ERROR, CHECK FOR MISSING SEPARATOR CARD AFTER S	017560	0000
	1HAFT SEGMENT DATA', 25X, -- OR --')	017570	0000
1504	FORMAT(/, FATAL ERROR, CHECK FOR MISSING SEPARATOR CARD AFTER S	017580	0000
	1HAFT DATA')	017590	0000
2000	FORMAT(/, FATAL ERROR, TUNNEL TYPE IN SEGMENT 'I5,' IN REACH',	017600	0000
	1I5,' WAS NOT SPECIFIED BY USING CODE 1, 2, OR 3')	017610	0000
2005	FORMAT(/, FATAL ERROR, EXCAVATION METHOD IN SEGMENT 'I5,' IN RE	017620	0000
	1ACH 'I5,' DOES NOT MATCH TUNNEL TYPE SPECIFIED')	017630	0000
2010	FORMAT(/, FATAL ERROR, LINING TYPE IN SEGMENT 'I5,' IN REACH',	017640	0000

(Continued)

COSTUN Listing (Continued)

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115 ' DOES NOT MATCH TUNNEL TYPE SPECIFIED' 017650 0000
2015 FORMAT(' FATAL ERROR, WATERTIGHT LINING REQUIREMENT IN SEGMENT 017660 0000
1, IS, ' IN REACH, IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLA 017670 0000
2NK) OR 1') 017680 0000
2017 FORMAT(' **** REMINDER **** ALL CUT AND COVER TUNNEL SEGMENT 017690 0000
1TS ARE DESIGNED AS WATERTIGHT -- INPUT IGNORED IN SEGMENT, IS, 017700 0000
2 ' IN REACH, IS, 20X, AND WATERTIGHT DESIGN USED') 017710 0000
2020 FORMAT(' FATAL ERROR, NO LINING OR SUPPORT WAS SPECIFIED IN SE 017720 0000
GMENT, IS, ' IN REACH, IS, ' BUT A WATERTIGHT TUNNEL WAS SPECIFIED') 017730 0000
2025 FORMAT(' **** WARNING **** GROUND WATER ELEVATION IN SEGMENT 017740 0000
1, IS, ' IN REACH, IS, ' IS EITHER ZERO OR BLANK - ELEVATION ZERO WI 017750 0000
2LL BE USED IN COMPUTATIONS, 5X, 114(1HX)) 017760 0000
2030 FORMAT(' FATAL ERROR, ROD IN SEGMENT, IS, ' IN REACH, IS, ' IS 017770 0000
1LESS THAN 25 IN A ROCK TUNNEL. USE SOFT GROUND OR CUT AND COVER') 017780 0000
2035 FORMAT(' **** WARNING **** ROD IN SEGMENT, IS, ' IN REACH, IS, 017790 0000
1 ' IS GREATER THAN 25 FOR A SOFT GROUND TUNNEL, 5X, 29(1HX)) 017800 0000
2040 FORMAT(' FATAL ERROR, SURFACE NODAL POINTS ABOVE SEGMENT, IS, 017810 0000
1 ' IN REACH, IS, ' ARE OUT OF SEQUENCE') 017820 0000
2045 FORMAT(' FATAL ERROR, ONE OR BOTH SURFACE NODAL POINTS ABOVE S 017830 0000
EGMENT, IS, ' IN REACH, IS, ' WERE NOT LISTED WITH OTHER NODAL POIN 017840 0000
1T DATA CARDS') 017850 0000
2050 FORMAT(' FATAL ERROR, SURFACE NODAL POINT ELEVATIONS IN SEGMENT 017860 0000
1, IS, ' IN REACH, IS, ' ARE BELOW TUNNEL ELEVATION') 017870 0000
2055 FORMAT(' FATAL ERROR, EFFECTIVE GRAIN SIZE IN SEGMENT, IS, ' IN 017880 0000
1 REACH, IS, ' WAS NOT INPUT') 017890 0000
2060 FORMAT(' FATAL ERROR, SOIL STRENGTH (PHI AND/OR COHESION) IN S 017900 0000
EGMENT, IS, ' IN REACH, IS, ' WAS NOT SPECIFIED') 017910 0000
2061 FORMAT(' **** WARNING **** POSSIBLE ERROR IN PERMEABILITY IN 017920 0000
1 SEGMENT, IS, ' IN REACH, IS, ' - INPUT IS GREATER THAN 10 CM/SEC, 017930 0000
25X, 12(1HX)) 017940 0000
2062 FORMAT(' **** WARNING **** FRICTION ANGLE IN SEGMENT, IS, ' I 017950 0000
N REACH, IS, ' IS GREATER THAN 45 DEGREES, 5X, 35(1HX)) 017960 0000
2063 FORMAT(' FATAL ERROR, FRICTION ANGLE IN SEGMENT, IS, ' IN REACH 017970 0000
1, IS, ' IS GREATER THAN 100. CHECK FOR NUMBER SHIFTED ON DATA CARD') 017980 0000
2064 FORMAT(' FATAL ERROR, UNIT WEIGHT OF SOIL IN SEGMENT, IS, ' IN 017990 0000
1 REACH, IS, ' IS TOO LARGE FOR SOIL OR POOR ROCK') 018000 0000
2065 FORMAT(' FATAL ERROR, DEWATERING REQUIREMENT IN SEGMENT, IS, 018010 0000
1 ' IN REACH, IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK) 018020 0000
2OR 1') 018030 0000
2070 FORMAT(' **** WARNING **** IMPERVIOUS LAYER ELEVATION IN SEG 018040 0000
MENT, IS, ' IN REACH, IS, ' IS EITHER ZERO OR BLANK - ELEVATION ZER 018050 0000
20 WILL BE USED IN COMPUTATIONS, 5X, 111(1HX)) 018060 0000
2072 FORMAT(' FATAL ERROR, IMPERVIOUS LAYER ELEVATION IN SEGMENT, 018070 0000
115, ' IN REACH, IS, ' IS ABOVE AVERAGE SURFACE ELEVATION') 018080 0000
2073 FORMAT(' FATAL ERROR, IMPERVIOUS LAYER ELEVATION IN SEGMENT, 018090 0000
115, ' IN REACH, IS, ' IS AT THE SURFACE AND SOIL GRAIN SIZE INPUT 018100 0000
2EXCEEDS 0.005') 018110 0000
2075 FORMAT(' FATAL ERROR, SUPPORT TYPE IN SOFT GROUND SEGMENT, 018120 0000
115, ' IN REACH, IS, ' WAS NOT SPECIFIED BY CODE 1, 2, 3, 4, 5, OR 6') 018130 0000
2080 FORMAT(' FATAL ERROR, SUPPORT TYPE IN SEGMENT, IS, ' IN REACH, 018140 0000
115, ' DOES NOT MATCH TUNNEL TYPE SPECIFIED') 018150 0000
2085 FORMAT(' FATAL ERROR, LINING TYPE IN SEGMENT, IS, ' IN REACH, 018160 0000
115, ' DOES NOT MATCH SUPPORT TYPE SPECIFIED') 018170 0000
2090 FORMAT(' **** WARNING **** ROCK ELEVATION IN SEGMENT, IS, 018180 0000
2 ' IN REACH, IS, ' IS EITHER ZERO OR BLANK - ELEVATION ZERO WILL B 018190 0000
2E USED IN COMPUTATIONS, 5X, 114(1HX)) 018200 0000
2092 FORMAT(' FATAL ERROR, ROCK ELEVATION IN SEGMENT, IS, ' IN REACH 018210 0000
1, IS, ' IS ABOVE AVERAGE SURFACE ELEVATION') 018220 0000

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(Continued)

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2094	FORMAT(//, **** WARNING **** CUT AND COVER BOX IN SEGMENT', IS,	018230	0000
1'	IN REACH', IS, EXCEEDS 100 FEET', 5X, 42(1H*))	018240	0000
2095	FORMAT(//, FATAL ERROR, OPEN CUT BRACING IN SEGMENT', IS, IN REA	018250	0000
1CH', IS, WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK), 1, 2, OR 3)	018260	0000	
2100	FORMAT(//, FATAL ERROR, BRACING CODE FOR VERTICAL OPEN CUT IN SE	018270	0000
1GMENT', IS, IN REACH', IS, WAS NOT SPECIFIED BY USING CODE 1, 2, OR	018280	0000	
1, 3)	018290	0000	
2105	FORMAT(//, FATAL ERROR, DECKING CODE IN SEGMENT', IS, IN REACH',	018300	0000
1IS, WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK) OR 1)	018310	0000	
2115	FORMAT(//, FATAL ERROR, STABILITY NUMBER IN SEGMENT', IS, IN REA	018320	0000
1CH', IS, IS TOO HIGH, EXCAVATION IS IMPOSSIBLE)	018330	0000	
2120	FORMAT(//, FATAL ERROR, STABILIZATION METHOD IN SEGMENT', IS, IN	018340	0000
1REACH', IS, WAS NOT SPECIFIED BY CODE ZERO(OR BLANK), 1, 2, OR 3)	018350	0000	
2125	FORMAT(//, FATAL ERROR, STABILIZATION USE CODE IN SEGMENT', IS,	018360	0000
1IN REACH', IS, WAS NOT SPECIFIED BY CODE 1, 2, 3, OR 4)	018370	0000	
2130	FORMAT(//, FATAL ERROR, AIR PRESSURE IN SEGMENT', IS, IN REACH',	018380	0000
1IS, WAS NOT SPECIFIED WHEN STABILITY NUMBER WAS INPUT AND AIR P	018390	0000	
RESSURE(//, STABILIZATION SPECIFIED)	018400	0000	
2135	FORMAT(//, FATAL ERROR, STABILITY NUMBER WAS SPECIFIED IN SEGME	018410	0000
1T' IS, IN REACH', IS, BUT STABILIZATION USE CODE DOES NE 4)	018420	0000	
2137	FORMAT(//, FATAL ERROR, AIR PRESSURE IS SPECIFIED IN SEGMENT', IS,	018430	0000
1IN REACH', IS, BUT STABILIZATION METHOD NOT COMPRESSED AIR)	018440	0000	
2140	FORMAT(//, FATAL ERROR, STABILIZATION USE CODE IN SEGMENT', IS,	018450	0000
1IN REACH', IS, DOES NOT AGREE WITH METHOD SPECIFIED)	018460	0000	
2145	FORMAT(//, **** WARNING **** STABILIZATION METHOD IN SEGMENT',	018470	0000
1IS, IN REACH', IS, IS NOT ACCEPTABLE', 5X, 39(1H*))	018480	0000	
2147	FORMAT(//, FATAL ERROR, INPUT IN SEGMENT', IS, IN REACH', IS,	018490	0000
1REQUIRES USE OF AN UNACCEPTABLE STABILIZATION METHOD)	018500	0000	
2150	FORMAT(//, FATAL ERROR, TUNNEL SIZE IN REACH', IS, INDICATES CU	018510	0000
1T AND COVER SECTION, BUT SHAPE CODE IS NOT ZERO)	018520	0000	
2151	FORMAT(//, FATAL ERROR, TUNNEL SHAPE IN REACH', IS, INDICATES C	018530	0000
1UT AND COVER SECTION, BUT SIZE IS SPECIFIED IN WRONG COLUMN)	018540	0000	
2152	FORMAT(//, FATAL ERROR, SHAPE IN REACH', IS, INDICATES CUT AND	018550	0000
1COVER, BUT A MUCK TRANSPORT METHOD WAS SPECIFIED)	018560	0000	
2153	FORMAT(//, FATAL ERROR, TUNNEL REACH', IS, IS NOT CUT AND COVER	018570	0000
1, BUT NO MUCK TRANSPORT METHOD WAS SPECIFIED)	018580	0000	
2155	FORMAT(//, FATAL ERROR, WORK HOURS IN REACH', IS, WERE NOT SPEC	018590	0000
1IFIED BY A NUMBER FROM 0 TO 24)	018600	0000	
2160	FORMAT(//, FATAL ERROR, WORK DAYS IN REACH', IS, WERE NOT SPECI	018610	0000
1FIED BY A NUMBER FROM 4 TO 7)	018620	0000	
2165	FORMAT(//, FATAL ERROR, ONE OR BOTH BOX DIMENSIONS IN REACH', IS,	018630	0000
1WERE NOT INPUT)	018640	0000	
2170	FORMAT(//, **** WARNING **** TOTAL CLEAR BOX WIDTH IN REACH',	018650	0000
1IS, EXCEEDS 40 FEET', 5X, 55(1H*))	018660	0000	
2175	FORMAT(//, FATAL ERROR, OPEN CUT IS SPECIFIED IN REACH', IS,	018670	0000
1AND NUMBER OF BOX UNITS NOT SPECIFIED FOR A SINGLE LEVEL BOX)	018680	0000	
2180	FORMAT(//, **** WARNING **** BOX HEIGHT IN REACH', IS, IS GRE	018690	0000
1ATER THAN 20 FEET FOR A SINGLE LEVEL BOX', 5X, 35(1H*))	018700	0000	
2185	FORMAT(//, **** WARNING **** TOTAL CLEAR BOX HEIGHT IN REACH',	018710	0000
1IS, IS GREATER THAN 40 FEET FOR A DOUBLE BOX', 5X, 39(1H*))	018720	0000	
2190	FORMAT(//, **** WARNING **** DEWATERING MAY BE USED AS A STABI	018730	0000
1LIZATION METHOD IN SEGMENT', IS, IN REACH', IS, AND IMPERVIOUS LA	018740	0000	
1YER IS 20X, INCORRECTLY PLACED ABOVE THE TUNNEL. ELIMP WILL BE	018750	0000	
1JASSUMED AT TUNNEL INVERT.)	018760	0000	
2195	FORMAT(//, FATAL ERROR, COMPRESSED AIR WAS REQUIRED IN SEGMENT',	018770	0000
1IS, IN REACH', IS, AND TRUCK MUCK TRANSPORT SPECIFIED)	018780	0000	
2200	FORMAT(//, FATAL ERROR, CAST IRON TUNNEL SUPPORT WAS SPECIFIED I	018790	0000
1N SEGMENT', IS, IN REACH', IS, BUT CIRCULAR SHAPE NOT SPECIFIED)	018800	0000	

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COSTUN Listing (Continued)

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2201 FORMAT(/, ' FATAL ERROR, SEGMENT', IS, ' IN REACH', IS, ' IS NOT CUT
1 AND COVER, BUT NO SHAPE WAS SPECIFIED') 018810 0000
2202 FORMAT(/, ' FATAL ERROR, SHAPE SPECIFIED FOR SEGMENT', IS, ' IN REA
1CH', IS, ' IS NOT FOR CUT AND COVER') 018820 0000
2203 FORMAT(/, ' **** WARNING **** SOUND ROCK ELEVATION LIES ABOVE B
1ASE OF TRENCH IN SEGMENT', IS, ' IN REACH', IS, ' AND RQD IS BETWEEN
225-50. //20X, RQD MAY BE TOO LOW FOR DESIGN AS SOUND ROCK. ) 018830 0000
2204 FORMAT(/, ' FATAL ERROR, SOUND ROCK ELEVATION LIES ABOVE BASE OF
1 TRENCH IN SEGMENT', IS, ' IN REACH', IS, ' AND RQD IS LESS THAN 25. //
2 13X, RQD IS TOO LOW FOR DESIGN AS SOUND ROCK') 018840 0000
2205 FORMAT(/, ' FATAL ERROR, DEWATERING MUST BE ALLOWED IN SLOPING CU
1T SEGMENT', IS, ' IN REACH', IS, ' BECAUSE WATER TABLE IS ABOVE BASE
2OF TRENCH AND //14X, ABOVE IMPERVIOUS LAYER ) 018850 0000
2207 FORMAT(/, ' FATAL ERROR, SHAFT TYPE IN SEGMENT', IS, ' IN SHAFT', IS,
1' WAS NOT SPECIFIED BY USING CODE 1,2,OR 3') 018860 0000
2208 FORMAT(/, ' **** WARNING **** NO METHOD OF EXCAVATION OR LININ
1G TYPE WERE INPUT FOR SEGMENT', IS, ' IN SHAFT', IS, ' A DUMMY SHAFT
2 IS ASSUMED') 018870 0000
2210 FORMAT(/, ' FATAL ERROR, EXCAVATION METHOD IN SEGMENT', IS, ' IN SH
1AFT', IS, ' DOES NOT MATCH SHAFT TYPE SPECIFIED') 018880 0000
2212 FORMAT(/, ' FATAL ERROR, RQD IN SEGMENT', IS, ' IN SHAFT', IS, ' IS
1LESS THAN 25 IN A ROCK SHAFT. USE SOFT GROUND OR CUT AND COVER') 018890 0000
2215 FORMAT(/, ' **** WARNING **** RQD IN SEGMENT', IS, ' IN SHAFT', IS,
1' IS GREATER THAN 25 FOR A SOFT GROUND SHAFT', 5X,30(1HX)) 018900 0000
2220 FORMAT(/, ' FATAL ERROR, LINING TYPE IN SEGMENT', IS, ' IN SHAFT',
1IS, ' DOES NOT MATCH SHAFT TYPE SPECIFIED') 018910 0000
2225 FORMAT(/, ' FATAL ERROR, WATERTIGHT LINING REQUIREMENT IN SEGMENT',
1IS, ' IN SHAFT', IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLA
1NK) OR 1') 018920 0000
2227 FORMAT(/, ' **** REMINDER **** ALL CUT AND COVER SHAFT SEGMENT
1S ARE DESIGNED AS WATERTIGHT -- INPUT IGNORED IN SEGMENT', IS,
2' IN SHAFT', IS, //20X, 'AND WATERTIGHT DESIGN USED') 018930 0000
2230 FORMAT(/, ' FATAL ERROR, NO LINING OR SUPPORT WAS SPECIFIED IN SE
1GMENT', IS, ' IN SHAFT', IS, ' BUT A WATERTIGHT SHAFT WAS SPECIFIED') 018940 0000
2235 FORMAT(/, ' **** WARNING **** GROUND WATER ELEVATION IN SEGMENT',
1IS, ' IN SHAFT', IS, ' IS EITHER ZERO OR BLANK - ELEVATION ZERO WI
2LL BE USED IN // COMPUTATIONS', 5X,114(1HX)) 018950 0000
2240 FORMAT(/, ' FATAL ERROR, GROUND WATER ELEVATION LOCATED WITHIN SE
1GMENT', IS, ' IN SHAFT', IS, ' - NEED TO DEFINE NEW SEGMENT AT GWT') 018960 0000
2245 FORMAT(/, ' FATAL ERROR, EFFECTIVE GRAIN SIZE IN SEGMENT', IS, ' IN
1SHAFT', IS, ' WAS NOT INPUT') 018970 0000
2250 FORMAT(/, ' FATAL ERROR, SOIL STRENGTH (PHI AND/OR COHESION) IN S
1EGMENT', IS, ' IN SHAFT', IS, ' WAS NOT SPECIFIED') 018980 0000
2251 FORMAT(/, ' **** WARNING **** POSSIBLE ERROR IN PERMEABILITY IN
1SEGMENT', IS, ' IN SHAFT', IS, ' - INPUT IS GREATER THAN 10 CM/SEC',
25X,12(1HX)) 018990 0000
2252 FORMAT(/, ' **** WARNING **** FRICTION ANGLE IN SEGMENT', IS, ' I
1N SHAFT', IS, ' IS GREATER THAN 45 DEGREES', 5X,35(1HX)) 019000 0000
2253 FORMAT(/, ' FATAL ERROR, FRICTION ANGLE IN SEGMENT', IS, ' IN SHAFT',
1IS, ' IS GREATER THAN 100.CHECK FOR NUMBER SHIFTED ON DATA CARD') 019010 0000
2254 FORMAT(/, ' FATAL ERROR, UNIT WEIGHT OF SOIL IN SEGMENT', IS, ' IN
1SHAFT', IS, ' IS TOO LARGE FOR SOIL OR POOR ROCK') 019020 0000
2255 FORMAT(/, ' FATAL ERROR, DEWATERING REQUIREMENT IN SEGMENT', IS,
1' IN SHAFT', IS, ' WAS NOT SPECIFIED BY USING CODE ZERO(OR BLANK)
2OR 1') 019030 0000
2260 FORMAT(/, ' **** WARNING **** IMPERVIOUS LAYER ELEVATION IN SEG
1MENT', IS, ' IN SHAFT', IS, ' IS EITHER ZERO OR BLANK - ELEVATION ZER
20 WILL BE USED // IN COMPUTATIONS', 5X,111(1HX)) 019040 0000
019050 0000
019060 0000
019070 0000
019080 0000
019090 0000
019100 0000
019110 0000
019120 0000
019130 0000
019140 0000
019150 0000
019160 0000
019170 0000
019180 0000
019190 0000
019200 0000
019210 0000
019220 0000
019230 0000
019240 0000
019250 0000
019260 0000
019270 0000
019280 0000
019290 0000
019300 0000
019310 0000
019320 0000
019330 0000
019340 0000
019350 0000
019360 0000
019370 0000
019380 0000

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A55

COSTUN Listing (Continued)

		019960 0000
		019970 0000
		019980 0000
		019990 0000
		020000 0000
		020010 0000
		020020 0000
		020030 0000
		020040 0000
		020050 0000
		020060 0000
		020070 0000
		020080 0000
		020090 0000
		020100 0000
		020110 0000
		020120 0000
		020130 0000
		020140 0000
		020150 0000
		020160 0000
		020170 0000
		020180 0000
		020190 0000
		020200 0000
		020210 0000
		020220 0000
		020230 0000
		020240 0000
		020250 0000
		020260 0000
		020270 0000
		020280 0000
		020290 0000
		020300 0000
		020310 0000
		020320 0000
		020330 0000
		020340 0000
		020350 0000
		020360 0000
		020370 0000
		020380 0000
		020390 0000
		020400 0000
		020410 0000
		020420 0000
		020430 0000
		020440 0000
		020450 0000
		020460 0000
		020470 0000
		020480 0000
		020490 0000
		020500 0000
		020510 0000
		020520 0000
		020530 0000

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-----
COMMON /BASIC/ NSS,NTS
COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE
COMMON /F/ IERROR,ISTOP
DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
1 TRDATA(NTRMAX,23)
-----

INITIALIZE

NPT=B(1,3)
NPB=B(1,4)
NSEGS=0
I=1
NSSEG1=1
-----

10 IP=I
   I=I+1
   NSEGS=NSEGS+1

CHECK FOR LAST SHAFT SEGMENT CARD
IF(I.GT.NSS) GO TO 30

SEE IF PREVIOUS SEGMENT WAS IN SAME SHAFT AS THIS SEGMENT
IF(B(I,1).EQ.B(IP,1)) GO TO 20
GO TO 30
20 NPB=B(I,4)
   GO TO 10
30 NSHAFT=B(IP,1)
   SHAFT(NSHAFT,1)=NSSEG1
   SHAFT(NSHAFT,2)=NPT
   SHAFT(NSHAFT,3)=NPB
   SHAFT(NSHAFT,4)=NSEGS
   IF(I.GT.NSS) GO TO 40
   NPT=B(I,3)
   NPB=B(I,4)
   NSSEG1=I
   NSEGS=0
   GO TO 10
-----

40 CONTINUE
CHECK FOR SHAFTS CONTAINING BOTH CUT AND COVER AND NON-CC SEGMENTS
DO 800 NSHAFT=1,NSMAX
  IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 800
  NSSEG1=SHAFT(NSHAFT,1)
  NSEGS=SHAFT(NSHAFT,4)
  DO 700 J=1,NSEGS
    NSSTYP=B(NSSEG1,15)
    IF(J.EQ.1) GO TO 700
    IF(NSSTYP.LT.3) GO TO 700
    SEGMENT IS IN CUT AND COVER
    IF(NSSTYP.EQ.B(NSSEG1-1,15)) GO TO 700
    ISTOP=1
    NSSEG=B(NSSEG1,2)
  
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COSTUN Listing (Continued)

	WRITE(LO,1000) NSSEG,NSHAFT	020540	0000
700	NSSEG1=NSSEG1+1	020550	0000
800	CONTINUE	020560	0000
C	-----	020570	0000
C	CHECK FOR ANY STOPS FOUND	020580	0000
	IF(ISTOP.EQ.0) RETURN	020590	0000
C	FATAL ERRORS DETECTED.TERMINATE RUN AND GO TO NEXT DATA DECK	020600	0000
	WRITE(LO,2000)	020610	0000
	CALL NEXSET(LO,LI)	020620	0000
C	-----	020630	0000
1000	FORMAT(// ' FATAL ERROR, SEGMENT',IS,' IN SHAFT',IS,' IS IN OUT	020640	0000
	LAND COVER,BUT NOT ALL OTHER SEGMENTS ARE')	020650	0000
2000	FORMAT(///,1X,119(1H*),/25X,'PROGRAM STOPPED BECAUSE OF ERRORS I	020660	0000
	IN SUBROUTINE SFTSET' ,/1X,119(1H*))	020670	0000
C	-----	020680	0000
C	-----	020690	0000
C	-----	020700	0000
	RETURN	020710	0000
	END	020720	0000

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COSTUN Listing (Continued)

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C      END
C      SUBROUTINE LENGTH (A,B,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NSSMAX,
C      INPMAX,NSMAX,NTRMAX)
C      -----
C      THIS SUBROUTINE CALCULATES ALL SEGMENT LENGTHS AND MUCK TRANSPORT
C      DISTANCES
C      -----
C      COMMON /BASIC/ NSS,NTS
C      COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE
C      COMMON /F/ IERROR,ISTOP
C      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
C      1 TRDATA(NTRMAX,23),CUMSL(NPMAX)
C      -----
C      CALCULATE SHAFT SEGMENT LENGTHS
C      DO 20 I=1,NSS
C      NPT=B(I,3)
C      NPB=B(I,4)
C      ELNPT=CNP(NPT,2)
C      ELNPB=CNP(NPB,2)
C      SSEGL=ELNPT-ELNPB
C      20 B(I,35)=SSEGL
C      -----
C      CALCULATE SHAFT HOISTING DISTANCES FOR EACH SEGMENT AND EACH SHAFT
C      SUM .....RUNNING SUM OF SHAFT SEGMENT LENGTHS IN SHAFT I
C      DO 50 I=1,NSMAX
C      IF(SHAFT(I,1).LT.-10.E29) GO TO 50
C      NSSEG1=SHAFT(I,1)
C      NSEGS=SHAFT(I,4)
C      SUM=0.
C      DO 40 J=1,NSEGS
C      SSEGL=B(NSSEG1,35)
C      HH=SUM+.5*SSEGL
C      B(NSSEG1,36)=HH
C      SUM=SSEGL+SUM
C      40 NSSEG1=NSSEG1+1
C      SHAFT(I,8)=SUM
C      CHECK FOR SHAFT DEPTH GREATER THAN 3000 FEET
C      IF(SHAFT(I,8).GT.3000.) WRITE(LO,1071) I
C      50 CONTINUE
C      -----
C      CALCULATE ACTUAL TUNNEL SEGMENT LENGTH (LENGTH ALONG THE SEGMENT).
C      AS AN INTERMEDIATE STEP, CALCULATE THE STATIONING OF THE TUNNEL
C      NODAL POINTS ALONG THE LENGTH OF THE SEGMENTS (NOT THE HORIZONTAL
C      LENGTH), AND THEN CALCULATE HORIZONTAL STATIONING
C      -----
C      STA=STABEG
C      NPL=A(1,2)
C      CUMSL(NPL)=0.0
C      CNP(NPL,1)=STABEG
C      DO 60 I=1,NTS
C      TSEGL=A(I,45)

```

```

020720 0000
020730 0000
020735 0000
020740 0000
020750 0000
020760 0000
020770 0000
020780 0000
020790 0000
020800 0000
020810 0000
020820 0000
020830 0000
020840 0000
020850 0000
020860 0000
020870 0000
020880 0000
020890 0000
020900 0000
020910 0000
020920 0000
020930 0000
020940 0000
020950 0000
020960 0000
020970 0000
020980 0000
020990 0000
021000 0000
021010 0000
021020 0000
021030 0000
021040 0000
021050 0000
021060 0000
021070 0000
021080 0000
021090 0000
021100 0000
021110 0000
021120 0000
021130 0000
021140 0000
021150 0000
021160 0000
021170 0000
021180 0000
021190 0000
021200 0000
021210 0000
021220 0000
021230 0000
021240 0000
021250 0000
021260 0000

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COSTUN Listing (Continued)

	NPL=A(I,2)	021270	0000
	NPR=A(I,3)	021280	0000
	ELNPL=CNP(NPL,2)	021290	0000
	ELNPR=CNP(NPR,2)	021300	0000
	SEGL=SQRT((ELNPL-ELNPR)**2+TSEGL**2)	021310	0000
	CUMSL(NPR)=CUMSL(NPL)+SEGL	021320	0000
	STA=STA+TSEGL	021330	0000
C	THE NEXT STATEMENT CONVERTS TSEGL FROM HORIZ. TO TRUE LENGTH	021340	0000
	TSEGL=SEGL	021350	0000
	A(I,45)=TSEGL	021360	0000
60	CNP(NPR,1)=STA	021370	0000
C	-----	021380	0000
C		021390	0000
C	CALCULATE AVERAGE MUCK TRANSPORTATION DISTANCES AND SLOPES (TO	021400	0000
C	MIDPOINT OF SEGMENTS) USING NODAL POINT STATIONING	021410	0000
C		021420	0000
	DO 70 I=1,NTS	021430	0000
	NPL=A(I,2)	021440	0000
	NPR=A(I,3)	021450	0000
	ELNPL=CNP(NPL,2)	021460	0000
	ELNPR=CNP(NPR,2)	021470	0000
	NREACH=A(I,4)	021480	0000
	NSHAFT=TRDATA(NREACH,1)	021490	0000
	NPBS=SHAFT(NSHAFT,3)	021500	0000
	ELNPBS=CNP(NPBS,2)	021510	0000
	DM=ABS(CUMSL(NPBS)-(CUMSL(NPL)+CUMSL(NPR))/2.)/5280.	021520	0000
	RL=DM*5280.+ABS(CUMSL(NPL)-CUMSL(NPR))/2.	021530	0000
C	CHECK FOR REACH LENGTH GREATER THAN 105600 FEET (20 MILES)	021540	0000
	IF(RL.GT.105600.) WRITE(LO,1061) NREACH	021550	0000
	A(I,46)=DM	021560	0000
C	CALCULATE ELEVATION DIFFERENCE FROM BASE OF SHAFT TO SEG. MIDPOINT	021570	0000
	ELEV=ELNPBS-(ELNPL+ELNPR)/2.	021580	0000
	HSLOPE=ELEV/SQRT((DM*5280.)**2-ELEV**2)	021590	0000
70	A(I,47)=HSLOPE	021600	0000
C	-----	021610	0000
C	CHECK FOR DUMMY SHAFT ADJACENT TO AT LEAST ONE CUT AND COVER REACH	021620	0000
	DO 200 I=1,NSMAX	021630	0000
	IF(SHAFT(I,1).LT.-10.E29) GO TO 200	021640	0000
	ISHAPS=SHAFT(I,16)	021650	0000
	IF(ISHAPS.NE.0) GO TO 200	021660	0000
	NPORT=SHAFT(I,23)	021670	0000
	IF(NPORT.EQ.1) GO TO 200	021680	0000
	NPBS=SHAFT(I,3)	021690	0000
	STA=CNP(NPBS,1)	021700	0000
	IF(STA.GT.STABEG) GO TO 100	021710	0000
	NTSTYP=A(I,16)	021720	0000
	IF(NTSTYP.EQ.3) GO TO 200	021730	0000
	GO TO 175	021740	0000
100	STA=STA-1.0	021750	0000
	IJK=0	021760	0000
	DO 150 J=1,NTS	021770	0000
	NPL=A(J,2)	021780	0000
	NPR=A(J,3)	021790	0000
	IF(STA.GT.CNP(NPL,1).AND.STA.LT.CNP(NPR,1)) GO TO 160	021800	0000
150	CONTINUE	021810	0000
160	NTSTYP=A(J,16)	021820	0000
	IF(NTSTYP.EQ.3) GO TO 200	021830	0000
	IF(J.EQ.NTS) GO TO 175	021840	0000

(Continued)

COSTUN Listing (Continued)

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NTSTYP=A(J+1,16)
IF(NTSTYP.EQ.3) GO TO 200
175 IERROR=1
WRITE(LO,2000) I
200 CONTINUE
-----
1061 FORMAT(/, ' **** WARNING ****   TOTAL LENGTH OF REACH', I5, ' EXCE
1EDS 20 MILES', 5X, 51(1HX))
1071 FORMAT(/, ' **** WARNING ****   SHAFT', I5, ' IS OVER 3000 FT DEEP'
15X, 63(1HX))
2000 FORMAT(/, ' FATAL ERROR, SHAFT', I5, ' IS A DUMMY SHAFT, BUT THERE
1 ARE NO ADJACENT CUT AND COVER REACHES')
RETURN
END
SUBROUTINE INOUT(I, A, B, CNP, SHAFT, TRDATA, NLINES, IP, NTSMAX, NSSMAX,
1NPMAX, NSMAX, NTRMAX)
-----
THIS SUBROUTINE LISTS OUT THE INPUT DATA
SEGMENTS ARE LISTED IN THE ORDER OF APPEARANCE ALONG THE ROUTE
I= SEGMENT SEQUENCE NUMBER, NUMBER IN ORDER OF APPEARANCE
-----
COMMON /BASIC/ NSS, NTS
COMMON /A/ LO, LI, PM, OM, LIST(40), TITLE(160), STABEG, ITYPE
1DIMENSION A(NTSMAX, 68), B(NSSMAX, 43), CNP(NPMAX, 2), SHAFT(NSMAX, 23),
1TRDATA(NTRMAX, 23)
DIMENSION FMT1(21), FMT2(15), FMT3(7), FMT4(20), FMT5(13)
*****
DOUBLE PRECISION STATEMENTS ARE REQUIRED FOR LITERALS HAVING
5 TO 8 CHARACTERS ON COMPUTERS THAT HAVE 4 CHARACTERS PER WORD,
SUCH AS THE IBM 360, FORTRAN IV COMPILER.
REMOVE THE FOLLOWING DOUBLE PRECISION STATEMENTS FOR COMPUTERS
THAT HAVE 6 CHARACTERS PER WORD SUCH AS THE UNIVAC 1108,
FORTRAN V COMPILER.
ALL LITERALS IN THIS SUBROUTINE HAVE A MAXIMUM OF 6 CHARACTERS
TO BE COMPATIBLE WITH BOTH SYSTEMS.
DOUBLE PRECISION BLANK, CONU, TMOLER, TMOLES, HANDS, RIPPER, VERTCC,
1SLOPCC, HORSE, BASKET, CIRCLE, BOX, TWOBOX, SQUARE, CONUYR, TRUCK, TRAIN,
2CONTRK, TNONE, JET, DRV, ANO, YES, CIRSEG, CONSEG, STLSET, STLSET, SOLDER,
3SLURRY, OPENCT, AIRPRS, DEWATR, GRDINJ, USENO, PREFNO, STRUT, ANCHOR,
4STRANC
DOUBLE PRECISION SHAPE, REMK, EXCAV, LTLIN, AR, TL, HOURS, DAYS, SUPORT,
1DWATER, STABIL, GAMMA, PERM, STABNO, AIRPR, DECK, BRACE, BFT, EXMS,
2SHAPS, GRDU
REAL*8 JBLANK, NONE, ISHOT, ICONC, IPREC, IFNEC, MUSTUS, IUSE, L'TYP
*****
CHARACTER*6 FM1/'2X,A6,/, FM2/'A5,/, FM3/'A5,/, FM4/'
1'1X,A4,/,
1FM5/'1X,A4,/, FM6/'5X,A4,/, FM7/'1X,A6,/, FM8/'4X,A6,/, FM9/'A6,/,
2FM10/'A6,/, FM11/'1X,I4,/, FM12/'F8.1,/, FM13/'F5.1,/,
3FM14/'F5.1,/, FM15/'15,/, FM16/'3X,I6,/, FM17/'F7.1,/,
4FM18/'E10.2,/, FM19/'F6.1,/, FM20/'F6.1,/, FM21/'F7.2,/,
5FM22/'3X,A4,/, FM23/'I7,/,

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(Continued)

COSTUN Listing (Continued)

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CHARACTER*6 FMT1/'(1X,I4',',I5',',I5',',I5',',I6',',I7,2X',',A6',', 022440 0000
1'F7.2'
1'2X,A6',',2X,A6',',F8.1',',3X,I6',',I5',',I5',',I5',',2X,A6',', 022450 0000
2'F5.1',',A6',',F7.1',',F5.1',',F5.1',', 022460 0000
CHARACTER*6 FMT2/'(10X',',I5,I5',',E10.2',',F7.1',',F5.0',', 022470 0000
1'F7.0',', 022480 0000
1'E10.2',',I5',',A6',',F8.1',',2X,A6',',F6.1',',1X,A6',',1X,A6',', 022490 0000
2'F6.1',', 022500 0000
CHARACTER*6 FMT3/'(10X',',F7.1',',1X,A6',',2X,A6',',I5',',F8.2',', 022510 0000
1'F7.2',', 022520 0000
CHARACTER*6 FMT4/'(1X,I4',',I5',',I5',',I6',',2X,A6',',F6.2',', 022530 0000
1'1X,A6',', 022540 0000
1'F8.1',',3X,I6',',I5',',A6',',A6',',F6.1',',A6',',F7.1',',I8',', 022550 0000
2'I7',',F9.1',',F6.1',',F5.1',', 022560 0000
CHARACTER*6 FMT5/'(20X',',F7.1',',F5.0',',F7.0',',E10.2',', 022570 0000
1'E10.2',', 022580 0000
1'4X,A6',',F8.1',',2X,A6',',F6.1',',2X,A6',',1X,A6',',F6.1',', 022590 0000
C ----- 022600 0000
DATA BLANK//',JBLANK//',IBLANK//', 022610 0000
DATA CONU//CONU//',TMOLER//MOLER//',TMOLES//MOLES//',HANDS//HAND 022620 0000
IS//',RIPPER//RIPPER//',VERTCC//VERTCC//',SLOPCC//SLOPCC//', 022630 0000
DATA HORSE//HORSE//',BASKET//BASKET//',CIRCLE//CIRCLE//',BOX//BOX 022640 0000
1//',TWOBOX//TWOBOX//',SQUARE//SQUARE//', 022650 0000
DATA CONUVR//CONUVR//',TRUCK//TRUCK//',TRAIN//TRAIN//',CONTRK//CONT 022660 0000
IRK// 022670 0000
DATA NONE//NONE//',TNONE//NONE//', 022680 0000
DATA ISHOT//SHOT//',ICONC//CONC//',IPREC//PRECST//', 022690 0000
DATA WET//WET//',DRY//DRY//', 022700 0000
DATA ANO//NO//',YES//YES//', 022710 0000
DATA CIRSEG//CIRSEG//',CONSEG//CONSEG//',STLSEG//STLSEG//',STLSET//S 022720 0000
ITLSET//',SOLDER//SOLDER//',SLURRY//SLURRY//',OPENCT//OPENCT//', 022730 0000
DATA AIRPRS//AIRPRS//',DEWATR//DEWATR//',GRDINJ//GRDINJ//', 022740 0000
DATA USENO//NO USE//',PREFNO//NOPREF//', 022750 0000
DATA IFNEC//IF NEC//',MUSTUS//MUST//', 022760 0000
DATA STRUT//STRUT//',ANCHOR//ANCHOR//',STRANC//STRANC//', 022770 0000
C ----- 022780 0000
IF(ITYPE.EQ.2) GO TO 150 022790 0000
IF(LIST(2).EQ.0) GO TO 10 022800 0000
C SET VALUES OF GAMMA, PERM, HOURS AND DAYS IF NOT INPUT 022810 0000
NREACH=A(I,4) 022820 0000
NTSTYP=A(I,16) 022830 0000
IF(NTSTYP.EQ.1) GO TO 5 022840 0000
IF(A(I,22).LT.0.1) A(I,22)=120. 022850 0000
IF(A(I,25).GT.10.E-10) PERM=A(I,25) 022860 0000
D10=A(I,19) 022870 0000
IF(A(I,25).LT.10.E-10) PERM=D10**2/10. 022880 0000
A(I,25)=PERM 022890 0000
5 CONTINUE 022900 0000
IF(TRDATA(NREACH,8).LT.0.1) TRDATA(NREACH,8)=24. 022910 0000
IF(TRDATA(NREACH,9).LT.0.1) TRDATA(NREACH,9)=6.0 022920 0000
RETURN 022930 0000
C ----- 022940 0000
C 10 NLines=NLines+1 022950 0000
C IF(NLines.LE.40) GO TO 30 022960 0000
C WRITE OUT COLUMN HEADINGS FOR TUNNEL SEGMENTS 022970 0000
C ----- 022980 0000

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(Continued)

COSTUN Listing (Continued)

	WRITE(LO,1000)	022570	0000
	WRITE(LO,1001)	022580	0000
	WRITE(LO,1002)	022590	0000
	NLINES=0	023000	0000
30	NREACH=A(I,4)	023010	0000
	NTSEQ=A(I,1)	023020	0000
	NSHAFT=TRDATA(NREACH,1)	023030	0000
	BFT=TRDATA(NREACH,2)	023040	0000
	IPR=IP	023050	0000
C	-----	023060	0000
C	FIND THE HORIZONTAL SEGMENT LENGTH OF EACH SEGMENT, HSEGL,	023070	0000
C	(HORIZONTAL SEGMENT LENGTH AS GIVEN IN THE INPUT	023080	0000
C	MUST BE CALCULATED SINCE IT WAS PREVIOUSLY DESTROYED WHEN	023090	0000
C	IT WAS CONVERTED TO LENGTH ALONG THE SEGMENT, TSEGL(I))	023100	0000
	NPL=A(I,2)	023110	0000
	NPR=A(I,3)	023120	0000
	SEGL=CNP(NPR,1)-CNP(NPL,1)	023130	0000
	LSEGL=SEGL	023140	0000
C	-----	023150	0000
C	FIND ALPHA NAME FOR SHAPE	023160	0000
40	ISHAPE=TRDATA(NREACH,3)	023170	0000
	IBOX2=TRDATA(NREACH,13)	023180	0000
	IF(ISHAPE.EQ.0) SHAPE=BOX	023190	0000
	IF(ISHAPE.EQ.0.AND.IBOX2.EQ.1) SHAPE=TUOBOX	023200	0000
	IF(ISHAPE.EQ.1) SHAPE=CIRCLE	023210	0000
	IF(ISHAPE.EQ.2) SHAPE=HORSE	023220	0000
	IF(ISHAPE.EQ.3) SHAPE=BASKET	023230	0000
C	-----	023240	0000
C	FIND THE ALPHA NAME FOR THE LINING TYPE	023250	0000
	LINING=A(I,10)	023260	0000
	IF(LINING.EQ.0) LTYP=NONE	023270	0000
	IF(LINING.EQ.1) LTYP=ICONC	023280	0000
	IF(LINING.EQ.2) LTYP=ISHOT	023290	0000
	IF(LINING.EQ.3) LTYP=IPREC	023300	0000
C	-----	023310	0000
C	FIND ALPHA NAME FOR MUCK TRANSPORT METHOD	023320	0000
50	MTM=TRDATA(NREACH,4)	023330	0000
	IF(MTM.EQ.1) REMK=TRUCK	023340	0000
	IF(MTM.EQ.2) REMK=CONVYR	023350	0000
	IF(MTM.EQ.3) REMK=TRAIN	023360	0000
	IF(MTM.EQ.4) REMK=CONTRK	023370	0000
C	-----	023380	0000
C	FIND ALPHA NAME FOR METHOD OF EXCAVATION	023390	0000
60	MEX=A(I,7)	023400	0000
	IF(MEX.EQ.1) EXCAU=CONU	023410	0000
	IF(MEX.EQ.2) EXCAU=TMOLER	023420	0000
	IF(MEX.EQ.3) EXCAU=TMOLCS	023430	0000
	IF(MEX.EQ.4) EXCAU=HANDS	023440	0000
	IF(MEX.EQ.5) EXCAU=RIPPER	023450	0000
	IF(MEX.EQ.6) EXCAU=UERTCC	023460	0000
	IF(MEX.EQ.7) EXCAU=SLOPCC	023470	0000
C	-----	023480	0000
C	FIND ALPHA NAME FOR WATERTIGHT REQUIREMENT	023490	0000
	LINUT=A(I,15)	023500	0000
	IF(LINUT.EQ.0) WTLIN=ANO	023510	0000
	IF(LINUT.EQ.1) WTLIN=YES	023520	0000
	NTSTYP=A(I,16)	023530	0000
	IF(NTSTYP.EQ.3) WTLIN=YES		

(Continued)

COSTUN Listing (Continued)

C	70	AR=A(I,8)	023540	0000
		JRS=A(I,5)	023550	0000
		JRQD=A(I,6)	023560	0000
		JRTEMP=A(I,12)	023570	0000
		INFLOW=A(I,9)	023580	0000
		IF(INFLOW.LT.0) INFLOW=0	023590	0000
		TL=A(I,11)	023600	0000
		IF(TL.LE.0.) TL=0.	023610	0000
		ELWATR=A(I,14)	023620	0000
		HOURS=TRDATA(NREACH,8)	023630	0000
		DAYS=TRDATA(NREACH,9)	023640	0000
			023650	0000
C		-----	023660	0000
C		CHECK TO SEE IF THIS IS THE SAME REACH AS FOR PREVIOUS SEGMENT	023670	0000
C	85	IF(IPR.EQ.NREACH) GO TO 90	023680	0000
		SET VALUES OF HOURS AND DAYS FOR PREVIOUS REACH IF NOT INPUT	023690	0000
		IF(I.EQ.1) GO TO 88	023700	0000
		N=A(I-1,4)	023710	0000
		IF(TRDATA(N,8).LT.0.1) TRDATA(N,8)=24.0	023720	0000
		IF(TRDATA(N,9).LT.0.1) TRDATA(N,9)=6.0	023730	0000
	88	WRITE(LO,1004)	023740	0000
	90	IF(IPR.EQ.NREACH) WRITE(LO,2000)	023750	0000
		NLINES=NLINES+1	023760	0000
		-----	023770	0000
C		ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN	023780	0000
C		VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA	023790	0000
	91	IF(AR.GT.0.0) GO TO 92	023800	0000
		AR=BLANK	023810	0000
		FMT1(11)=FM1	023820	0000
	92	IF(TL.GT.0.0) GO TO 93	023830	0000
		TL=BLANK	023840	0000
		FMT1(17)=FM2	023850	0000
	93	IF(HOURS.GT.0.0) GO TO 94	023860	0000
		HOURS=BLANK	023870	0000
		FMT1(20)=FM2	023880	0000
	94	IF(DAYS.GT.0.0) GO TO 95	023890	0000
		DAYS=BLANK	023900	0000
		FMT1(21)=FM3	023910	0000
	95	IF(IPR.NE.NREACH) GO TO 98	023920	0000
		NREACH=IBLANK	023930	0000
		FMT1(1)=FM4	023940	0000
		HOURS=BLANK	023950	0000
		FMT1(20)=FM2	023960	0000
		DAYS=BLANK	023970	0000
		FMT1(21)=FM3	023980	0000
	98	IF(NTSTYP.GT.1) GO TO 100	023990	0000
		-----	024000	0000
C		ROCK TUNNEL	024010	0000
C		WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK,	024020	0000
		1EXCAV,AR,JRS,JRQD,JRTEMP,INFLOW,LTYP,TL,WTIN,ELWATR,HOURS,DAYS	024030	0000
		GO TO 140	024040	0000
		-----	024050	0000
C		SOFT GROUND TUNNEL OR CUT AND COVER BOX	024060	0000
C		FIND ALPHA NAME FOR SUPPORT TYPE	024070	0000
	100	ISUPPT=A(I,26)	024080	0000
		IF(ISUPPT.EQ.0) SUPORT=TNONE	024090	0000
		IF(ISUPPT.EQ.1) SUPORT=CIRSEG	024100	0000
		IF(ISUPPT.EQ.2) SUPORT=CONSEG	024110	0000

(Continued)

CQSTUN Listing (Continued)

	IF(ISUPPT.EQ.3) SUPORT=STLSEG	024120	0000
	IF(ISUPPT.EQ.4) SUPORT=STLSET	024130	0000
	IF(ISUPPT.EQ.5) SUPORT=SOLDER	024140	0000
	IF(ISUPPT.EQ.6) SUPORT=SLURRY	024150	0000
C	FIND ALPHA NAME FOR ALLOWING DEWATERING	024160	0000
	IWATER=A(I,23)	024170	0000
	IF(IWATER.EQ.0) DWATER=ANO	024180	0000
	IF(IWATER.EQ.1) DWATER=YES	024190	0000
	NPLS=A(I,17)	024200	0000
	NPRS=A(I,18)	024210	0000
	D10=A(I,19)	024220	0000
	PHI=0.0	024230	0000
	COHESN=0.0	024240	0000
	IF(A(I,20).GT.0.0) PHI=A(I,20)	024250	0000
	IF(A(I,21).GT.0.0) COHESN=A(I,21)	024260	0000
	GAMMA=A(I,22)	024270	0000
	ELIMP=A(I,24)	024280	0000
	PERM=A(I,25)	024290	0000
	STABNO=A(I,30)	024300	0000
C	FIND ALPHA NAME FOR USE OF STABILIZATION METHOD	024310	0000
	MUST=A(I,32)	024320	0000
	IF(MUST.EQ.2) IUSE=IFNEC	024330	0000
	IF(MUST.EQ.3) IUSE=IFNEC	024340	0000
	IF(MUST.EQ.4) IUSE=MUSTUS	024350	0000
	AIRPR=A(I,33)	024360	0000
C	FIND ALPHA NAME FOR STABILIZATION METHOD	024370	0000
	MSTAB=A(I,31)	024380	0000
	IF(MSTAB.EQ.0.AND.MUST.LE.2) STABIL=PREFNO	024390	0000
	IF(MSTAB.EQ.0.AND.MUST.EQ.4) STABIL=USENO	024400	0000
	IF(MSTAB.EQ.1) STABIL=AIRPRS	024410	0000
	IF(MSTAB.EQ.2) STABIL=DEWATR	024420	0000
	IF(MSTAB.EQ.3) STABIL=GRDINJ	024430	0000
C	ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN	024440	0000
C	VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA	024450	0000
C	DO NOT PRINT TEMPERATURE UNDER ROCK LISTING	024460	0000
	JRTEMP=IBLANK	024470	0000
	FMT1(14)=FMS	024480	0000
105	IF(JRS.GT.0) GO TO 106	024490	0000
	JRS=IBLANK	024500	0000
	FMT1(12)=FMS	024510	0000
106	IF(JRQD.GT.0) GO TO 107	024520	0000
	JRQD=IBLANK	024530	0000
	FMT1(13)=FMS	024540	0000
107	IF(GAMMA.GT.0.0) GO TO 108	024550	0000
	GAMMA=BLANK	024560	0000
	FMT2(4)=FM7	024570	0000
108	IF(PERM.GT.0.0) GO TO 109	024580	0000
	PERM=BLANK	024590	0000
	FMT2(7)=FMS	024600	0000
109	IF(STABNO.GT.0.0) GO TO 110	024610	0000
	STABNO=BLANK	024620	0000
	FMT2(12)=FMS	024630	0000
110	IF(MUST.GT.1) GO TO 112	024640	0000
	IUSE=JBLANK	024650	0000
112	IF(AIRPR.GT.0.0) GO TO 118	024660	0000
	AIRPR=BLANK	024670	0000
	FMT2(15)=FM10	024680	0000
118	IF(NTSTYP.EQ.3) GO TO 120	024690	0000

(Continued)

COSTUN Listing (Continued)

C	-----	024700	0000
C	SOFT GROUND TUNNEL	024710	0000
	WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK,	024720	0000
	1EXCAU,AR,JRS,JROD,JRTEMP,INFLOW,LTYP,TL,UTLIN,ELWATR,HOURS,DAYS	024730	0000
	JRTEMP=A(I,12)	024740	0000
	WRITE(LO,FMT2) NPLS,NPRS,D10,GAMMA,PHI,COHESN,PERM,JRTEMP,DWATER,	024750	0000
	1ELIMP,SUPORT,STABNO,STABIL,IUSE,AIRPR	024760	0000
	NLINES=NLINES+1	024770	0000
	GO TO 140	024780	0000
C	-----	024790	0000
C	CUT AND COVER	024800	0000
C	FIND ALPHA NAMES FOR DECKING REQUIREMENT	024810	0000
120	IDECK=A(I,29)	024820	0000
	IF(IDECK.EQ.0) DECK=NO	024830	0000
	IF(IDECK.EQ.1) DECK=YES	024840	0000
C	FIND ALPHA NAME FOR BRACING SPECIFIED	024850	0000
	IBRACE=A(I,28)	024860	0000
	IF(IBRACE.EQ.0) BRACE=NONE	024870	0000
	IF(IBRACE.EQ.1) BRACE=STRUT	024880	0000
	IF(IBRACE.EQ.2) BRACE=ANCHOR	024890	0000
	IF(IBRACE.EQ.3) BRACE=STRANC	024900	0000
	ELROCK=A(I,27)	024910	0000
	NREACH=A(I,4)	024920	0000
	NBOX=TRDATA(NREACH,10)	024930	0000
	BFBWDT=TRDATA(NREACH,11)	024940	0000
	BFBHT=TRDATA(NREACH,12)	024950	0000
C	ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN	024960	0000
C	VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA	024970	0000
C	REMOVE TUNNEL SIZE, MUCK TRANSPORT, SOIL TEMPERATURE, AND	024980	0000
C	STABILIZATION FOR CUT AND COVER.	024990	0000
	IF(IPR.EQ.NREACH) NREACH=IBLANK	025000	0000
	BFT=BLANK	025010	0000
	FMT1(8)=FM7	025020	0000
	REMK=BLANK	025030	0000
	JRTEMP=IBLANK	025040	0000
	FMT2(8)=FM5	025050	0000
	IF(INFLOW.GT.0) GO TO 138	025060	0000
	INFLOW=IBLANK	025070	0000
	FMT1(15)=FM5	025080	0000
	STABIL=BLANK	025090	0000
138	WRITE(LO,FMT1) NREACH,NTSEG,NPL,NPR,NSHAFT,LSEGL,SHAPE,BFT,REMK,	025100	0000
	1EXCAU,AR,JRS,JROD,JRTEMP,INFLOW,LTYP,TL,UTLIN,ELWATR,HOURS,DAYS	025110	0000
	WRITE(LO,FMT2) NPLS,NPRS,D10,GAMMA,PHI,COHESN,PERM,JRTEMP,DWATER,	025120	FMT0
	1ELIMP,SUPORT,STABNO,STABIL,IUSE,AIRPR	025130	FMT0
	WRITE(LO,FMT3) ELROCK,DECK,BRACE,NBOX,BFBWDT,BFBHT	025140	0000
	NLINES=NLINES+2	025150	0000
C	-----	025160	0000
140	NREACH=A(I,4)	025170	0000
	IF(IPR.NE.NREACH) IPR=NREACH	025180	0000
C	SET VALUE FOR GAMMA IN THIS TUNNEL SEGMENT IF NOT INPUT	025190	0000
	IF(NTSTYP.GT.1.AND.A(I,22).LT.0.1) A(I,22)=120.0	025200	0000
C	SET VALUE FOR PERMEABILITY IF NOT INPUT	025210	0000
	IF(NTSTYP.GT.1.AND.A(I,25).GT.10.E-10) PERM=PERM	025220	0000
	IF(NTSTYP.GT.1.AND.A(I,25).LT.10.E-10) PERM=D10**2/10.	025230	0000
	A(I,25)=PERM	025240	0000
	IP=IPR	025250	0000
C	RESET FORMATS TO ORIGINAL IN DATA STATEMENT	025260	0000
	FMT1(1)=FM11	025270	0000

(Continued)

COSTUN Listing (Continued)

	FMT1(11)=FM12	025220	0000
	FMT1(17)=FM13	025230	0000
	FMT1(20)=FM13	025300	0000
	FMT1(21)=FM14	025310	0000
	IF(NTSTYP.EQ.1) GO TO 145	025320	0000
	FMT1(14)=FM15	025330	0000
	FMT1(12)=FM16	025340	0000
	FMT1(13)=FM15	025350	0000
	FMT2(4)=FM17	025360	0000
	FMT2(7)=FM18	025370	0000
	FMT2(12)=FM19	025380	0000
	FMT2(15)=FM20	025390	0000
	IF(NTSTYP.EQ.2) GO TO 145	025400	0000
	FMT1(8)=FM21	025410	0000
	FMT2(8)=FM15	025420	0000
	FMT1(15)=FM15	025430	0000
145	CONTINUE	025440	0000
	IF(I+1.LE.NTS) RETURN	025450	0000
C	SET HOURS AND DAYS FOR LAST REACH IF NOT INPUT	025460	0000
	IF(TRDATA(NREACH,8).LT.0.1) TRDATA(NREACH,8)=24.0	025470	0000
	IF(TRDATA(NREACH,9).LT.0.1) TRDATA(NREACH,9)=6.0	025480	0000
	WRITE(LO,1004)	025490	0000
	RETURN	025500	0000
C	*****	025510	0000
C	*****	025520	0000
C	*****	025530	0000
C	*****	025540	0000
C	*****	025550	0000
150	IF(LIST(3).EQ.0) GO TO 200	025560	0000
C	SET VALUES OF GAMMA, PERM, HOURS AND DAYS IF NOT INPUT	025570	0000
	NSHAFT=B(I,1)	025580	0000
	NSSTYP=B(I,15)	025590	0000
	IF(NSSTYP.EQ.1) GO TO 160	025600	0000
	IF(B(I,18).LT.0.1) B(I,18)=120.	025610	0000
	IF(B(I,23).GT.10.E-10) PERM=-B(I,23)	025620	0000
	D10=B(I,16)	025630	0000
	IF(B(I,23).LT.10.E-10) PERM=D10**2/10.	025640	0000
	B(I,23)=PERM	025650	0000
160	CONTINUE	025660	0000
	IF(SHAFT(NSHAFT,17).LT.0.1) SHAFT(NSHAFT,17)=24.	025670	0000
	IF(SHAFT(NSHAFT,18).LT.0.1) SHAFT(NSHAFT,18)=6.0	025680	0000
	RETURN	025690	0000
C	WRITE OUT THE DATA CONCERNING THE SHAFTS	025700	0000
C		025710	0000
C		025720	0000
C		025730	0000
C		025740	0000
200	NLINES=NLINES+1	025750	0000
	IF(NLINES.LE.45) GO TO 230	025760	0000
C		025770	0000
	WRITE(LO,1010)	025780	0000
	WRITE(LO,1011)	025790	0000
	NLINES=0	025800	0000
230	NSHAFT=B(I,1)	025810	0000
	NSSEQ=B(I,2)	025820	0000
	BFS=SHAFT(NSHAFT,7)	025830	0000
	NPT=B(I,3)	025840	0000
	NPB=B(I,4)	025850	0000

(Continued)

COSTUN Listing (Continued)

	NPORT=SHAFT(NSHAFT,23)	025860	0000
	NPTS=SHAFT(NSHAFT,2)	025870	0000
	NPDS=SHAFT(NSHAFT,3)	025880	0000
	JRS=B(I,5)	025890	0000
	JRQD=B(I,6)	025900	0000
	NSSTYP=B(I,15)	025910	0000
	IPS=IP	025920	0000
C	-----	025930	0000
C	FIND THE ALPHA NAME FOR THE LINING TYPE	025940	0000
	LINING=B(I,10)	025950	0000
	IF(LINING.EQ.0) LTYP=NONE	025960	0000
	IF(LINING.EQ.1) LTYP=CONC	025970	0000
	IF(LINING.EQ.2) LTYP=ISHOT	025980	0000
	IF(LINING.EQ.3) LTYP=IPREC	025990	0000
C	-----	026000	0000
C	FIND ALPHA NAME FOR EXCAVATION METHOD	026010	0000
240	MEX=B(I,7)	026020	0000
	IF(MEX.EQ.0) EXMS=NONE	026030	0000
	IF(MEX.EQ.1) EXMS=CONU	026040	0000
	IF(MEX.EQ.2) EXMS=TMOLER	026050	0000
	IF(MEX.EQ.3) EXMS=TMOLCS	026060	0000
	IF(MEX.EQ.4) EXMS=HANDS	026070	0000
C	FIND ALPHA NAME FOR SHAFT SHAPE	026080	0000
	ISHAPS=SHAFT(NSHAFT,16)	026090	0000
	IF(ISHAPS.EQ.1) SHAPS=CIRCLE	026100	0000
	IF(ISHAPS.EQ.2) SHAPS=SQUARE	026110	0000
C	FIND ALPHA NAME FOR WATERTIGHT REQUIREMENT	026120	0000
	LINUT=B(I,14)	026130	0000
	IF(LINUT.EQ.0) WTLIN=NO	026140	0000
	IF(LINUT.EQ.1) WTLIN=YES	026150	0000
	IF(NSSTYP.EQ.3) WTLIN=YES	026160	0000
	ELWATR=B(I,13)	026170	0000
	HOURS=SHAFT(NSHAFT,17)	026180	0000
	DAYS=SHAFT(NSHAFT,18)	026190	0000
C	-----	026200	0000
C	AR=B(I,8)	026210	0000
	FIND ALPHA NAME FOR SHAFT GROUNDWATER INFLOW	026220	0000
	INFLOW=B(I,9)	026230	0000
	IF(INFLOW.EQ.1) GRDW=WET	026240	0000
	IF(INFLOW.EQ.0) GRDW=DRY	026250	0000
C	-----	026260	0000
	TL=B(I,11)	026270	0000
	IF(TL.EQ.0) TL=0.	026280	0000
	DDS=SHAFT(NSHAFT,5)	026290	0000
	IARTEM=SHAFT(NSHAFT,11)	026300	0000
260	ICDS=SHAFT(NSHAFT,6)	026310	0000
C	-----	026320	0000
C	SEE IF THE SHAFT FOR THIS SEGMENT IS SAME AS PREVIOUS SHAFT	026330	0000
285	IF(IPS.EQ.NSHAFT) GO TO 290	026340	0000
C	SET VALUES OF HOURS AND DAYS FOR PREVIOUS SHAFT IF NOT INPUT	026350	0000
	IF(I.EQ.1) GO TO 288	026360	0000
	N=B(I-1,1)	026370	0000
	IF(SHAFT(N,17).LT.0.1) SHAFT(N,17)=24.0	026380	0000
	IF(SHAFT(N,18).LT.0.1) SHAFT(N,18)=6.0	026390	0000
288	WRITE(LO,1004)	026400	0000
290	IF(IPS.EQ.NSHAFT) WRITE(LO,2000)	026410	0000
	NLINES=NLINES+1	026420	0000
C	CHECK FOR PORTAL	026430	0000

(Continued)

COSTUN Listing (Continued)

	IF(NPORT.EQ.0) GO TO 292	026440 0000
	WRITE(LO,2200) NSHAFT,NPTS,DDS,ICDS,IARTEN	026450 0000
	GO TO 350	026460 0000
C	-----	026470 0000
	DUMMY SHAFT IS INPUT WHEN NO SHAFT IS REQUIRED FOR OPEN CUT REACH	026480 0000
C	292 IF(ISHAPS.NE.0) GO TO 300	026490 0000
	WRITE(LO,2100) NSHAFT,NSSEG,NPTS,NPBS,DDS,ICDS,IARTEN	026500 0000
	GO TO 350	026510 0000
C	-----	026520 0000
C	ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN	026530 0000
C	VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA	026540 0000
	300 IF(AR.GT.0.0) GO TO 301	026550 0000
	AR=BLANK	026560 0000
	FMT4(8)=FM1	026570 0000
	301 IF(TL.GT.0.0) GO TO 302	026580 0000
	TL=BLANK	026590 0000
	FMT4(13)=FM9	026600 0000
	302 IF(HOURS.GT.0.0) GO TO 303	026610 0000
	HOURS=BLANK	026620 0000
	FMT4(19)=FM9	026630 0000
	303 IF(DAYS.GT.0.0) GO TO 305	026640 0000
	DAYS=BLANK	026650 0000
	FMT4(20)=FM3	026660 0000
	305 IF(IPS.NE.NSHAFT) GO TO 308	026670 0000
	NSHAFT=IBLANK	026680 0000
	FMT4(1)=FM4	026690 0000
	HOURS=BLANK	026700 0000
	FMT4(19)=FM9	026710 0000
	DAYS=BLANK	026720 0000
	FMT4(20)=FM3	026730 0000
	308 IF(NSSTYP.GT.1) GO TO 310	026740 0000
C	-----	026750 0000
C	ROCK SHAFT	026760 0000
	WRITE(LO,FMT4) NSHAFT,NSSEG,NPT,NPB,SHAPS,BFS,EXMS,AR,JRS,JRQD,	026770 0000
	1GRDU,LTP,TL,UTLIN,DDS,ICDS,IARTEN,ELUATR,HOURS,DAYS	026780 0000
	GO TO 350	026790 0000
C	-----	026800 0000
C	SOFT GROUND SHAFT OR CUT AND COVER	026810 0000
C	FIND ALPHA NAME FOR ALLOWING DEWATERING	026820 0000
	310 IWATER=B(I,21)	026830 0000
	IF(IWATER.EQ.0) DWATER=ANO	026840 0000
	IF(IWATER.EQ.1) DWATER=YES	026850 0000
C	FIND ALPHA NAME FOR SUPPORT TYPE	026860 0000
	ISUPPT=B(I,22)	026870 0000
	IF(ISUPPT.EQ.1) SUPORT=CIRSEG	026880 0000
	IF(ISUPPT.EQ.2) SUPORT=CONSEG	026890 0000
	IF(ISUPPT.EQ.3) SUPORT=STLSEG	026900 0000
	IF(ISUPPT.EQ.4) SUPORT=STLSET	026910 0000
	IF(ISUPPT.EQ.5) SUPORT=OPENCT	026920 0000
	D10=B(I,16)	026930 0000
	GAMMA=B(I,18)	026940 0000
	PHI=0.0	026950 0000
	COHESN=0.0	026960 0000
	IF(B(I,19).GT.0.0) PHI=B(I,19)	026970 0000
	IF(B(I,17).GT.0.0) COHESN=B(I,17)	026980 0000
	PERM=B(I,23)	026990 0000
	ELIMP=B(I,20)	027000 0000
	STABNO=B(I,24)	027010 0000

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COSTUN Listing (Continued)

C	FIND ALPHA NAME FOR USE OF STABILIZATION METHOD	027020	0000
	MUST=B(I,26)	027030	0000
	IF(MUST.EQ.2)IUSE=IFNEC	027040	0000
	IF(MUST.EQ.3)IUSE=IFNEC	027050	0000
	IF(MUST.EQ.4)IUSE=MUSTUS	027060	0000
	AIRPR=B(I,27)	027070	0000
C	FIND ALPHA NAME FOR STABILIZATION METHOD	027080	0000
	MSTAB=B(I,25)	027090	0000
	IF(MSTAB.EQ.0.AND.MUST.LE.2) STABIL=PREFNO	027100	0000
	IF(MSTAB.EQ.0.AND.MUST.EQ.4) STABIL=USENO	027110	0000
	IF(MSTAB.EQ.1) STABIL=AIRPRS	027120	0000
	IF(MSTAB.EQ.2) STABIL=DEUATR	027130	0000
	IF(MSTAB.EQ.3) STABIL=GRDINJ	027140	0000
C	ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN	027150	0000
C	VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA	027160	0000
	IF(GAMMA.GT.0.0) GO TO 320	027170	0000
	GAMMA=BLANK	027180	0000
	FMT5(3)=FM7	027190	0000
320	IF(PERM.GT.0.0) GO TO 321	027200	0000
	PERM=BLANK	027210	0000
	FMT5(6)=FM8	027220	0000
321	IF(STABNO.GT.0.0) GO TO 322	027230	0000
	STABNO=BLANK	027240	0000
	FMT5(10)=FM9	027250	0000
322	IF(MUST.GT.1) GO TO 324	027260	0000
	IUSE=JBLANK	027270	0000
324	IF(AIRPR.GT.0.0) GO TO 325	027280	0000
	AIRPR=BLANK	027290	0000
	FMT5(13)=FM10	027300	0000
325	IF(JRS.GT.0) GO TO 326	027310	0000
	JRS=IBLANK	027320	0000
	FMT4(9)=FM6	027330	0000
326	IF(JRQD.GT.0) GO TO 329	027340	0000
	JRQD=IBLANK	027350	0000
	FMT4(10)=FM5	027360	0000
329	IF(NSSTVP.EQ.3) GO TO 330	027370	0000
C	-----	027380	0000
C	SOFT GROUND SHAFT	027390	0000
	WRITE(LO,FMT4) NSHAFT,NSSEG,NPT,NPB,SHAPS,BFS,EXMS,AR,JRS,JRQD,	027400	0000
	1GRDW,LTYP,TL,WTLIN,DDS,ICDS,IARTEM,ELWATR,HOURS,DAYS	027410	0000
	WRITE(LO,0006) D10,GAMMA,PHI,COMESH,PERM,DWATER,ELIMP,SUPORT,	027420	0000
	1STABNO,STABIL,IUSE,AIRPR	027430	0000
	NLINES=NLINES+1	027440	0000
	GO TO 350	027450	0000
C	-----	027460	0000
C	CUT AND COVER	027470	0000
C	SHAFT IS BUILT WITHIN OPEN CUT CONSTRUCTED FOR TUNNEL	027480	0000
C	ADJUST FORMAT AND WRITE STATEMENTS TO PUT BLANKS IN OUTPUT WHEN	027490	0000
C	VARIABLE CHECKED IS NOT SPECIFIED IN INPUT DATA	027500	0000
C	REMOVE VARIABLES THAT DO NOT APPLY TO CUT AND COVER	027510	0000

(Continued)

COSTUN Listing (Continued)

C	ORDU, IARTEN, DUATER, ELIMP, STABIL	027520	0000
330	ORDU=BLANK	027530	0000
	IARTEN=IBLANK	027540	0000
	FMT4(17)=FM22	027550	0000
	DUATER=BLANK	027560	0000
	ELIMP=BLANK	027570	0000
	FMT5(8)=FM1	027580	0000
	STABIL=BLANK	027590	0000
	WRITE(LO, FMT4) NSHAFT, NSSEG, NPT, NPB, SHAPS, BFS, EXMS, AR, JRS, JRQD,	027600	0000
	1ORDU, LTYF, TL, UTLIN, DDS, ICDS, IARTEN, ELUATR, HOURS, DAYS	027610	0000
	WRITE(LO, 0000) D10, GAMMA, PHI, COMESH, PERM, DUATER, ELIMP, SUPORT,	027620	0000
	1STABNO, STABIL, IUSE, AIRPR	027630	0000
	NLINES=NLINES+1	027640	0000
C	-----	027650	0000
360	NSHAFT=B(I,1)	027660	0000
	IF(IPS.NE.NSHAFT) IPS=NSHAFT	027670	0000
C	SET VALUE FOR GAMMA IN THIS SHAFT SEGMENT IF NOT INPUT	027680	0000
	IF(NSSTYP.GT.1.AND.B(I,18).LT.0.1) B(I,18)=120.0	027690	0000
	IF(NSSTYP.GT.1.AND.B(I,23).GT.10.E-10) PERM=-PERM	027700	0000
	IF(NSSTYP.GT.1.AND.B(I,23).LT.10.E-10) PERM=D10**2/10.	027710	0000
	B(I,23)=PERM	027720	0000
	IP=IPS	027730	0000
C	RESET FORMATS TO ORIGINAL IN DATA STATEMENT	027740	0000
	FMT4(1)=FM11	027750	0000
	FMT4(8)=FM12	027760	0000
	FMT4(13)=FM19	027770	0000
	FMT4(19)=FM19	027780	0000
	FMT4(20)=FM14	027790	0000
	IF(NSSTYP.EQ.1) GO TO 360	027800	0000
	FMT5(3)=FM17	027810	0000
	FMT5(6)=FM18	027820	0000
	FMT5(10)=FM19	027830	0000
	FMT5(13)=FM20	027840	0000
	FMT4(9)=FM16	027850	0000
	FMT4(10)=FM15	027860	0000
	IF(NSSTYP.EQ.2) GO TO 360	027870	0000
	FMT4(17)=FM23	027880	0000
	FMT5(8)=FM12	027890	0000
360	CONTINUE	027900	0000
	IF(I+1.LE.NSS) RETURN	027910	0000
C	SET HOURS AND DAYS FOR LAST SHAFT IF NOT INPUT	027920	0000
	IF(SHAFT(NSHAFT,17).LT.0.1) SHAFT(NSHAFT,17)=24.0	027930	0000
	IF(SHAFT(NSHAFT,18).LT.0.1) SHAFT(NSHAFT,18)=6.0	027940	0000
	WRITE(LO,1004)	027950	0000
C		027960	0000

(Continued)

COSTUN Listing (Continued)

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C      *****
C      RETURN
C      *****
1000 FORMAT(1H1,49(1H), ' T U N N E L I N P U T D A T A ',47(1H)//
11X, 'REACH SEG NP BOUNDARY EXIT HORIZ TUNNEL TUNNEL MUCK EXCAV
2A- UNF ADU XROCK PROPERTIESX INFLOW XXX LINING XXX GROUND HOURS D
3AYS'/11X, 'LEFT RIGHT SHAFT LENGTH SHAPE SIZE REMOVAL TION
4RATE STRENGTH ROD TEMP (GPM) TYPE THICK UAT WATER PER PER
5/43X, '(FT) METHOD METHOD (FT/DAY) (PSI)',7X, '(F)',15X, '(IN) T
6GT ELEV. DAY WEEK')
1001 FORMAT(33(2X,2H--)/13X, 'SURFACE ',12(1H), ' SOIL PROPERTIES ',13(
11H), ' DEUT- IMPERU SUPPORT XXXXX STABILIZATION XXXX'/11X, 'NP BO
2UNDY GRN SIZE UNIT WT PHI COHESION PERM. TEMP ERING LAYER TY
3PE NUMBER METHOD USE AIRPR'/11X, 'LEFT RIGHT (M M) (PCF)
4 (PSF) (CM/SEC) (F) ALLOW ELEV. ',30X, '(PSI)')
1002 FORMAT(33(2X,2H--)/11X, 'SOUND X CUT AND COVER XXXX PROPERTIESXX'
1/11X, 'ROCK DECKING BRACING UNITS WIDTH HEIGHT'/11X, 'ELEV. ',25X,
2'(FT) (FT)')
1004 FORMAT(1X,131(1H--))
1010 FORMAT(1H1,50(1H), ' S H A F T I N P U T D A T A ',48(1H)//
11X, 'SHAFT SEG NP BOUNDARY SHAFT SHAFT EXCAVA- UNF ADU XROCK PROP.
2X INFLOW XXX LINING XXXX DISPOSAL DISPOSAL ABOVE GROUND HOURS DAY
3S'/11X, 'UPPER LOWER SHAPE SIZE TION RATE STRENGTH ROD
4 TYPE THICK UAT DISTANCE COST GRND. WATER PER PER'/31X,
5'(FT) METHOD (FT/DAY) (PSI)',20X, '(IN) TGT (MILES) (S/ACRE) TEM
6P ELEV. DAY WEEK')
1011 FORMAT(33(2X,2H--)/22X,11(1H), ' SOIL PROPERTIES ',10(1H), ' DEU
1AT- IMPERU SUPPORT XXXXX STABILIZATION XXXX'/22X, 'GRN SIZE UNIT
2 WT PHI COHESION PERM. ERING LAYER TYPE NUMBER METHOD
3 USE AIRPR'/23X, '(M M) (PCF) (PSF) (CM/SEC) ALLOW
4 ELEV. ',30X, '(PSI)')
2000 FORMAT(1X)
2100 FORMAT(1X,14,15,15,16,10X, 'THIS SHAFT IS A DUMMY',36X,F7.1,I8,I7)
2200 FORMAT(15,14X, 'THIS SHAFT AT NODAL POINT',14, ' IS ACTUALLY A
1PORTAL',14X,F10.1,I8,I7)
0001 FORMAT(/,1X,14,15,15,15,16,17,2X,A6,F7.2,2X,A6,2X,A6,F8.1,3X,I6,
115,15,15,2X,A6,F5.1,A6,F7.1,F5.1,F5.1,/)
0002 FORMAT(/,10X,15,15,E10.2,F7.1,F5.0,F7.0,E10.2,15,A6,F8.1,2X,A6,
1F6.1,1X,A6,1X,A6,F6.1,/)
0003 FORMAT(/,10X,F7.1,1X,A6,2X,A6,15,F8.2,F7.2,/)
0004 FORMAT(/,1X,14,15,15,16,2X,A6,F6.2,1X,A6,F8.1,3X,I6,15,A6,A6,F6.1,
1A6,F7.1,I8,I7,F9.1,F6.1,F5.1,/)
0006 FORMAT(/,20X,E10.2,F7.1,F5.0,F7.0,E10.2,4X,A6,F8.1,2X,A6,F6.1,2X,
1A6,1X,A6,F6.1,/)
END
027970 0000
027980 0000
027990 0000
028000 0000
028010 0000
028020 0000
028030 0000
028040 0000
028050 0000
028060 0000
028070 0000
028080 0000
028090 0000
028100 0000
028110 0000
028120 0000
028130 0000
028140 0000
028150 0000
028160 0000
028170 0000
028180 0000
028190 0000
028200 0000
028210 0000
028220 0000
028230 0000
028240 0000
028250 0000
028260 0000
028270 0000
028280 0000
028290 0000
028300 0000
028310 0000
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028334 0000
028335 0000
028336 0000
028337 0000
028338 0000
028339 0000
028340 0000
028345 0000

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	SUBROUTINE SIZEST(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX	028350	0000
	1,NTRMAX)	028355	
	-----	028360	0000
	I-TUNNEL OR SHAFT SEGMENT NUMBER	028370	0000
	THIS SUBROUTINE CALCULATES THE FOLLOWING IN TUNNELS OR SHAFTS	028380	0000
	BE, BE40, BE60, TL, BOB, BOB40, BOB60, WEB, TPLATE, TSEG, DTRNCH, SIDEL, UBOX,	028390	0000
	TUOL, FORMAR, WTUALE, WTSTRT, WTANCH, UTSP, UTSPD	028400	0000
	-----	028410	0000
		028420	0000
		028430	0000
		028440	0000
	*****	028450	0000
	GENERAL DATA	028460	0000
	*****	028470	0000
		028480	0000
	COMMON /BASIC/ NSS,NTS	028490	0000
	COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE	028500	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	028510	0000
	1 TRDATA(NTRMAX,23)	028520	0000
	REAL MIN,MAX	028530	0000
		028540	0000
	I-TUNNEL SEGMENT SEQUENCE NUMBER	028550	0000
		028560	0000
	ITYPE=1 INDICATES TUNNEL SEGMENT	028570	0000
	ITYPE=1	028580	0000
	NREACH=A(I,4)	028590	0000
	NTSEG=A(I,1)	028600	0000
	TLIN=A(I,11)	028610	0000
	BFT=TRDATA(NREACH,2)	028620	0000
	BF=BFT	028630	0000
	LINING=A(I,10)	028640	0000
	MEK=A(I,7)	028650	0000
	ISHAPE=TRDATA(NREACH,3)	028660	0000
	MSTAKE=0	028670	0000
	ELWATR=A(I,14)	028680	0000
	NPL=A(I,2)	028690	0000
	NPR=A(I,3)	028700	0000
	ELNPL=CNP(NPL,2)	028710	0000
	ELNPR=CNP(NPR,2)	028720	0000
	ELAUG=(ELNPL+ELNPR)/2.	028730	0000
	LINUT=A(I,15)	028740	0000
	NTSTYP=A(I,16)	028750	0000
	NSSTYP=0	028760	0000
	GO TO 10	028770	0000
		028780	0000

(Continued)

COSTUN Listing (Continued)

C	-----	028790	0000
C	ENTRY SIZES(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,	028800	0000
	INTRMAX)	028810	0000
C	I=SHAFT SEGMENT SEQUENCE NUMBER	028815	
C	ITYPE=2 INDICATES SHAFT SEGMENT	028820	0000
	ITYPE=2	028830	0000
	TLIN=B(I,11)	028840	0000
	NSHAFT=B(I,1)	028850	0000
	ISHAPS=SHAFT(NSHAFT,16)	028860	0000
	IF(ISHAPS.EQ.0) RETURN	028870	0000
	NPORT=SHAFT(NSHAFT,23)	028880	0000
	IF(NPORT.EQ.1) RETURN	028890	0000
	NSSEQ=B(I,2)	028900	0000
	BFS=SHAFT(NSHAFT,7)	028910	0000
	BFB=BFS	028920	0000
	LINING=B(I,10)	028930	0000
	MEX=B(I,7)	028940	0000
	MSTAKE=0	028950	0000
	ELUATR=B(I,13)	028960	0000
	LINUT=B(I,14)	028970	0000
	NSSTYP=B(I,15)	028980	0000
	NTSTYP=0	028990	0000
	NPT=B(I,3)	029000	0000
	NPB=B(I,4)	029010	0000
	ELNPT=CNP(NPT,2)	029020	0000
	ELNPB=CNP(NPB,2)	029030	0000
	ELAUG=(ELNPT+ELNPB)/2.	029040	0000
		029050	0000
		029060	0000
		029070	0000
	-----	029080	0000
	CONVERT TL TO FEET	029090	0000
C	10 TLIN=TLIN/12.	029100	0000
C	IS IT A ROCK TUNNEL OR SHAFT	029110	0000
	IF(NTSTYP.EQ.1.OR. NSSTYP.EQ.1) GO TO 15	029120	0000
C	IS IT A SHAFT	029130	0000
	IF(ITYPE.EQ.2) GO TO 12	029140	0000
	PHI=A(I,20)	029150	0000
	NPLS=A(I,17)	029160	0000
	NPRS=A(I,18)	029170	0000
	ELNPLS=CNP(NPLS,2)	029180	0000
	ELNPBS=CNP(NPRS,2)	029190	0000
	ELSURF=(ELNPLS+ELNPBS)/2.	029200	0000
	GAMMA=A(I,22)	029210	0000
	CONESN=A(I,21)	029220	0000
	ISUPPT=A(I,26)	029230	0000
	GO TO 13	029240	0000
	12 PHI=B(I,19)	029250	0000
	GAMMA=B(I,18)	029260	0000
	CONESN=B(I,17)	029270	0000
	ISUPPT=B(I,22)	029280	0000
	NPTS=SHAFT(NSHAFT,2)	029290	0000
	ELSURF=CNP(NPTS,2)	029300	0000
	13 PI=3.14159	029310	0000
	DWATER=ELSURF-ELUATR	029320	0000
	ICUTNC=0	029330	0000
C	IS IT A SOFT GROUND TUNNEL OR SHAFT	029340	0000
		029350	0000

(Continued)

COSTUN Listing (Continued)

	IF(NTSTYP.EQ.2 .OR. NSTYP.EQ.2) GO TO 1000	029360	0000
	GO TO 2900	029370	0000
		029380	0000
		029390	0000
		029400	0000
	*****	029410	0000
	ROCK TUNNEL OR SHAFT	029420	0000
	*****	029430	0000
		029440	0000
	II IS A FLOW INDICATOR	029450	0000
15	II=4	029460	0000
	-----	029470	0000
	LINING FOR WATER PRESSURE	029480	0000
	-----	029490	0000
	PWATER=62.4*(ELWATR-ELAUG)	029500	0000
	IF(ITYPE.EQ.1) RQD=A(I,6)	029510	0000
	IF(ITYPE.EQ.2) RQD=B(I,6)	029520	0000
	UED =0.	029530	0000
	IF THE WATER LOAD IS ZERO, ASSIGN PWATER=0.001 FOR ESTIMATING	029540	0000
	LINING THICKNESS (ZERO VALUE MAY MAKE RESULT INDEFINITE)	029550	0000
	IF(PWATER.LE.0.001) PWATER=0.001	029560	0000
	IF(LINWT.EQ.0) PWATER=0.001	029570	0000
	IF(ITYPE.EQ.2) GO TO 21	029580	0000
	GO TO(21,22,23),ISHAPE	029590	0000
21	TL=0.5*BF*PWATER/(288000.-PWATER)	029600	0000
	GO TO 30	029610	0000
22	TL=0.77E-10*BF**0.86*PWATER**1.9*EXP(SQRT((16.9-1.42*XALOG(PWATER))	029620	0000
	1**2+0.32))	029630	0000
	GO TO 30	029640	0000
23	TL=3.8E-7*(7.+4.6*BF)*PWATER**1.035*EXP(SQRT((6.5-0.565*XALOG	029650	0000
	1(PWATER))**2+0.17))	029660	0000
	SET MIN. CONCRETE THICKNESS TO BE 8 INCHES. IF SHOTCRETE	029670	0000
	THICKNESS NOT INPUT, SET MIN. TO BE 3 INCHES	029680	0000
30	IF(LINING.EQ.1 .AND. TL.LT.0.6666) TL=0.6666	029690	0000
	IF(LINING.EQ.2 .AND. TLIN.LT.0.001 .AND. TL.LT.0.25) TL=0.25	029700	0000
	-----	029710	0000
	FLOW CONTROLLED BY RQD VALUE	029720	0000
	-----	029730	0000
	IF(RQD.GE.60.) GO TO 200	029740	0000
	IF(RQD.LE.40.) GO TO 100	029750	0000
	RQD LIES BETWEEN 40 AND 60, INTERPOLATION OF SIZES IS NECESSARY.	029760	0000
	SIZE WILL BE COMPUTED FOR RQD=40 AND RQD=60 BEFORE INTERPOLATING	029770	0000
	TO OBTAIN SIZE AT ACTUAL RQD	029780	0000
	II=1	029790	0000
	STORE THE ACTUAL VALUES OF LINING THICKNESS AND RQD	029800	0000
	RQDD=RQD	029810	0000
	TT=TL	029820	0000
	ASSIGN A FICTICIOUS RQD FOR THE FIRST PART OF INTERPOLATION COMP	029830	0000
	RQD=40	029840	0000
	-----	029850	0000
	RQD IS 40 OR LESS	029860	0000
	-----	029870	0000
	HAS A LINING THICKNESS BEEN INPUT. IF SO, COMPUTE AND STORE	029880	0000
	EXCAVATED DIMENSION USING THIS THICKNESS	029890	0000
	CHECK FOR CIRCULAR SHAPE	029900	0000
100	IF(ISHAPE.EQ.1) GO TO (110,120),MEX	029910	0000
	SHAPE IS HORSESHOE OR BASKETHANDLE	029920	0000
	COMPUTE DEPTH OF STEEL RIB SUPPORT	029930	0000

(Continued)

COSTUN Listing (Continued)

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      WEB = (0.2942BF+3.35 )/12.                                029940 0000
      GO TO 145                                                    029950 0000
C     CONVENTIONAL EXCAVATION                                     029960 0000
110  WEB = (0.2542BF+0.17-0.064XRQD)/12.                         029970 0000
      GO TO 130                                                    029980 0000
C     MOLE EXCAVATION                                             029990 0000
120  WEB = (0.2072BF+0.138-0.052XRQD)/12.                       030000 0000
130  IF(WEB*12..LT.4.0) WEB =4./12.                               030010 0000
C     IS SEGMENT LINED OR UNLINED                                030020 0000
145  IF(LINING.GT.0) GO TO 150                                     030030 0000
C     NO LINING                                                  030040 0000
      BE=BF+WEB*2.                                                 030050 0000
      TL=0.0                                                       030060 0000
      GO TO 400                                                    030070 0000
C     LINED                                                       030080 0000
C     CHECK FOR LINING TYPE                                       030090 0000
150  IF(LINING.EQ.1) GO TO 170                                     030100 0000
C     CALCULATE EXCAVATED DIMENSION FOR SHOTCRETE               030110 0000
      IF(TLIN.GT.0.001) GO TO 160                                   030120 0000
C     CHECK IF RIB THICKNESS + 3 IN. .GE. THE LINING THICKNESS 030130 0000
152  IF(WEB +0.25 .GE. TL) GO TO 155                             030140 0000
      BE=BF+2.*TL                                                 030150 0000
      GO TO 400                                                    030160 0000
155  BE=BF+WEB*2.+0.5                                             030170 0000
      GO TO 400                                                    030180 0000
C     CHECK IF THE GIVEN LINING THICKNESS .LT. THAT FOR WATER PRESSURE
160  IF(TLIN.LT.TL) MSTAKE=2                                       030190 0000
      IF(TLIN.LT.TL) GO TO 152                                     030200 0000
      TL=TLIN                                                      030210 0000
165  IF(WEB +0.25.GE.TL) GO TO 155                               030220 0000
      BE=BF+2.*TLIN                                                030230 0000
      GO TO 400                                                    030240 0000
C     CONCRETE                                                    030250 0000
170  TLMIN=WEB +0.333                                             030260 0000
      IF(TL.LT.TLMIN) TL=TLMIN                                     030270 0000
C     WAS A LINING THICKNESS INPUT                               030280 0000
      IF(TLIN.GT.0.001) GO TO 175                                 030290 0000
174  BE=BF+2.*TL                                                 030300 0000
      GO TO 400                                                    030310 0000
C     CHECK IF THE GIVEN LINING THICKNESS .GE. MINIMUM DIM. REQUIRED
175  IF(TLIN.GE.TLMIN) GO TO 176                                   030320 0000
C     ERROR - TL INPUT IS NOT THICK ENOUGH, PRINT WARNING      030330 0000
C     WAS THIS A TUNNEL OR SHAFT                                  030340 0000
      IF(ITYPE.EQ.1) WRITE(LO,1010) NTSEG,NREACH                 030350 0000
      IF(ITYPE.EQ.2) WRITE(LO,1011) NSSEG,NSHAFT                 030360 0000
      MSTAKE=1                                                      030370 0000
      GO TO 174                                                    030380 0000
C     CHECK IF THE GIVEN LINING THICKNESS .LT. THAT FOR WATER PRESSURE
176  IF(TLIN.LT.TL) GO TO 177                                     030390 0000
      BE=BF+2.*TLIN                                                030400 0000
      TL=TLIN                                                      030410 0000
      GO TO 400                                                    030420 0000
177  MSTAKE=8                                                      030430 0000
      GO TO 174                                                    030440 0000
C     -----                                                    030450 0000
C     RQD IS GREATER THAN OR EQUAL TO 60                         030460 0000
C     -----                                                    030470 0000
C     -----                                                    030480 0000
C     -----                                                    030490 0000
C     -----                                                    030500 0000
C     -----                                                    030510 0000

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(Continued)

COSTUN Listing (Continued)

C	HAS A LINING THICKNESS BEEN INPUT	030520 0000
200	IF(TLIN.GT.0.001) GO TO 230	030530 0000
C	IS SEGMENT LINED OR UNLINED	030540 0000
C	IF(LINING.GT.0)GO TO 216	030550 0000
C	UNLINED	030560 0000
	TL=0.0	030570 0000
	BE=BF	030580 0000
	GO TO 400	030590 0000
216	BE=BF+2.*TL	030600 0000
	GO TO 400	030610 0000
C	LINING TYPE	030620 0000
230	IF(LINING.EQ.2) GO TO 250	030630 0000
C	CONCRETE	030640 0000
	IF(TLIN.LT.0.666) GO TO 260	030650 0000
	GO TO 250	030660 0000
C	INPUT ERROR - TL INPUT IS NOT THICK ENOUGH, USE TL=0.667	030670 0000
C	IF ERROR MESSAGE WAS ALREADY PRINTED,SKIP IT NOW	030680 0000
260	IF(MSTAKE.EQ.1) GO TO 216	030690 0000
	IF(ITYPE.EQ.1) WRITE(LO,1010) NTSEG,NREACH	030700 0000
	IF(ITYPE.EQ.2) WRITE(LO,1011) NSSEG,NSHAFT	030710 0000
	GO TO 216	030720 0000
C	CHECK IF THE GIVEN LINING THICKNESS .LT. THAT FOR WATER PRESSURE	030730 0000
250	IF(TLIN.LT.TL) GO TO 275	030740 0000
	BE=BF+2.*TLIN	030750 0000
	TL=TLIN	030760 0000
	GO TO 400	030770 0000
275	MSTAKE=2	030780 0000
	GO TO 216	030790 0000
C	-----	030800 0000
C	OVERBREAK DIMENSION	030810 0000
C	-----	030820 0000
C	WHAT IS THE EXCAVATION METHOD	030830 0000
400	IF(NEX.EQ.2) BOB=BE	030840 0000
	IF(NEX.EQ.1) BOB=BE+(250.-RQD)*(BE+10.)/2500.	030850 0000
C	-----	030860 0000
C	RQD BETWEEN 40 AND 60	030870 0000
C	-----	030880 0000
C	IF(II.LT.3) GO TO 450	030890 0000
	BE40=BE	030900 0000
	BE60=BE	030910 0000
	BOB40=BOB	030920 0000
	BOB60=BOB	030930 0000
	GO TO 600	030940 0000
450	IF(II.GE.2) GO TO 500	030950 0000
C	STORE BE AND BOB COMPUTED USING FICTICIOUS RQD=40	030960 0000
	BE40=BE	030970 0000
	BOB40=BOB	030980 0000
C	REDEFINE RQD TO A FICTICIOUS VALUE OF 60 FOR SECOND PART OF	030990 0000
C	INTERPOLATION COMPUTATION	031000 0000
	RQD=60.	031010 0000
C	RE-ESTABLISH INPUT VALUE OF LINING THICKNESS FOR PURPOSES OF	031020 0000
C	THE CHECK IN STATEMENT 200	031030 0000
	TL=TT	031040 0000
C	REDEFINE FLOW INDICATOR	031050 0000
	II=II+1	031060 0000
	GO TO 200	031070 0000
C		031080 0000
		031090 0000

(Continued)

COSTUN Listing (Continued)

C	-----	031100	0000
C	500 STORE BE AND BOB COMPUTED USING FICTICIOUS RQD=60	031110	0000
C	BE40=BE	031120	0000
C	BOB40=BOB	031130	0000
C		031140	0000
C	CALCULATE BE AND BOB BY INTERPOLATING BETWEEN BE AND BOB	031150	0000
C	VALUES AT RQD=40 AND RQD=60	031160	0000
C		031170	0000
C	BE=BE40+(RQDD-40.)/20.*(BE60-BE40)	031180	0000
C	BOB=BOB40+(RQDD-40.)/20.*(BOB60-BOB40)	031190	0000
C	550 IF(LINING.NE.1) GO TO 600	031200	0000
C	COMPUTE THE AVERAGE THICKNESS FOR THE CONCRETE LINING	031210	0000
C	WHEN THE RQD IS BETWEEN 40 AND 60	031220	0000
C	TL=(BE-BF)/2.	031230	0000
C		031240	0000
C		031250	0000
C	-----	031260	0000
C	SET VARIABLES FOR SHAFT OR TUNNEL SEGMENTS	031270	0000
C	-----	031280	0000
C	600 IF(ITYPE.EQ.2) GO TO 700	031290	0000
C	TUNNEL SEGMENT DATA	031300	0000
C	A(I,39)=BE	031310	0000
C	A(I,40)=BE40	031320	0000
C	A(I,41)=BE60	031330	0000
C	A(I,42)=BOB	031340	0000
C	A(I,43)=BOB40	031350	0000
C	A(I,44)=BOB60	031360	0000
C	A(I,62)=UEB	031370	0000
C	A(I,64)=PUATER	031380	0000
C	A(I,11) = TL	031390	0000
C	IF(MSTAKE.EQ.2) WRITE(LO,2710) NTSEG,NREACH	031400	0000
C	GO TO 4000	031410	0000
C		031420	0000
C	SHAFT SEGMENT DATA	031430	0000
C	700 B(I,29)=BE	031440	0000
C	B(I,30)=BE40	031450	0000
C	B(I,31)=BE60	031460	0000
C	B(I,32)=BOB	031470	0000
C	B(I,33)=BOB40	031480	0000
C	B(I,34)=BOB60	031490	0000
C	B(I,41)=UEB	031500	0000
C	B(I,43)=PUATER	031510	0000
C	B(I,11) = TL	031520	0000
C	IF(MSTAKE.EQ.2) WRITE(LO,2711) NSSEG,NSHAFT	031530	0000
C	GO TO 4000	031540	0000
C		031550	0000
C		031560	0000
C	*****	031570	0000
C	SOFT GROUND TUNNELS AND SHAFTS	031580	0000
C	*****	031590	0000
C	1000 BE=BF	031600	0000
C	N=0	031610	0000
C	I2=0	031620	0000
C	TANPHI=TAN(PHI*PI/180.)	031630	0000
C		031640	0000
C	-----	031650	0000
C	MINIMUM SUPPORT SIZE	031660	0000
C	-----	031670	0000

(Continued)

COSTUN Listing (Continued)

C	GO TO(1001,1002,1003,1005),ISUPPT	031680	0000
	CAST IRON SEGMENTED SUPPORT	031650	0000
1001	TSEGMN=0.6666	031700	0000
	TPLMIN=0.06	031710	0000
	FF=4	031720	0000
	GO TO 1004	031730	0000
C	PRECAST CONCRETE SEGMENTED SUPPORT	031740	0000
1002	TSEGMN=1	031750	0000
	TPLMIN=0.125	031760	0000
	FF=2	031770	0000
	GO TO 1004	031780	0000
C	STEEL SEGMENTED SUPPORT	031790	0000
1003	TSEGMN=0.583	031800	0000
	TPLMIN=0.03	031810	0000
	FF=4	031820	0000
1004	IF(TLIN.GT.0. .AND. TLIN.LT.TPLMIN) GO TO 1008	031830	0000
	IF(TLIN.GT.TPLMIN) GO TO 1025	031840	0000
	GO TO 1009	031850	0000
1025	IF(ELUATR.LT.ELAUG .OR. LINWT.EQ.0) GO TO 1026	031860	0000
	GO TO 1009	031870	0000
C	WHEN WATER PRESSURE=0, INPUT LINER THICKNESS GREATER THAN MINIMUM	031880	0000
C	VALUE WILL BE ACCEPTED	031890	0000
1026	I2=1	031900	0000
	TPLATE=TLIN	031910	0000
	GO TO 2354	031920	0000
C	STEEL SEGMENTED SUPPORT	031930	0000
1005	IF(LINING.EQ.2) GO TO 1006	031940	0000
	TLIN=0.6666	031950	0000
	IF(TLIN.GT.0. .AND. TLIN.LT.TLMIN) GO TO 1008	031960	0000
	GO TO 1009	031970	0000
1006	TLMIN=0.333	031980	0000
	IF(TLIN.GT.0.) TLMIN=0	031990	0000
	GO TO 1009	032000	0000
C	INPUT LINER OR LINING THICKNESS LESS THAN MINIMUM VALUE	032010	0000
1008	MSTAKE=1	032020	0000
C	-----	032030	0000
C	UNIT WEIGHT OF SOIL	032040	0000
C	-----	032050	0000
1009	BDEE=2E	032060	0000
	N=N+1	032070	0000
	SEGDEP=ELSURF-ELAUG	032080	0000
C	CHECK FOR GWT ABOVE GROUND SURFACE	032090	0000
	IF(ELUATR.GT.ELSURF) GO TO 1045	032100	0000
C	CHECK FOR SEGMENT BELOW GWT	032110	0000
	IF(ELAUG.LT.ELUATR) GO TO 1015	032120	0000
C	GWT IS BELOW SEGMENT	032130	0000
	SIGGAH=SEGDEP*GAMMA	032140	0000
	IF(SEGDEP.LE.2.*BDE) GO TO 1012	032150	0000
	GAMMAA=GAMMA	032160	0000
	GAMMA2=GAMMA	032170	0000
	GO TO 1050	032180	0000
1012	GAMMAC=GAMMA	032190	0000
	GO TO 1050	032200	0000
C	SEGMENT IS BELOW GWT	032210	0000
1015	SIGGAH=DUATER*GAMMA+(ELUATR-ELAUG)*(GAMMA-62.4)	032220	0000
	IF(SEGDEP.LE.2.*BDE) GO TO 1030	032230	0000
	IF(DUATER.GT.2.*BDE) GO TO 1020	032240	0000
C	SEGMENT IS DEEPER THAN 2BE AND GWT IS WITHIN 2BE OF GROUND SURFACE	032250	0000

(Continued)

COSTUN Listing (Continued)

	GAMMA=(GAMMAXDUATER+(GAMMA-62.4)*(2.8BE-DUATER))/(2.8BE)	032260	0000
	GAMMA3=(GAMMA-62.4)	032270	0000
	GO TO 1050	032280	0000
C	SEGMENT AND OUT ARE BOTH DEEPER THAN 2BE	032290	0000
1080	GAMMA=GAMMA	032300	0000
	GAMMA3=(GAMMAX(DUATER-2.8BE)+(GAMMA-62.4)*(ELWATR-ELAUG))	032310	0000
	1/(SEGDEP-2.8BE)	032320	0000
	GO TO 1050	032330	0000
C	SEGMENT IS WITHIN 2BE OF GROUND SURFACE	032340	0000
1030	GAMMAC=(GAMMAXDUATER+(GAMMA-62.4)*(ELWATR-ELAUG))/SEGDEP	032350	0000
	GO TO 1050	032360	0000
C	OUT IS ABOVE GROUND SURFACE	032370	0000
1045	GAMMA=GAMMA-62.4	032380	0000
	GAMMA3=GAMMA-62.4	032390	0000
	GAMMAC=GAMMA-62.4	032400	0000
	SIGGAH=SEGDEP*(GAMMA-62.4)	032410	0000
C	ADJUST UNIT WEIGHTS OF SOIL FOR DRAINED SEGMENT	032420	0000
1050	IF(LINUT.EQ.1) GO TO 1100	032430	0000
	GAMMA=GAMMA	032440	0000
	GAMMA3=GAMMA	032450	0000
	GAMMAC=GAMMA	032460	0000
C	-----	032470	0000
C	EXPRESS SOIL STRENGTH IN TERMS OF EQUIVALENT PHI	032480	0000
C	-----	032490	0000
1100	PHIEQR=ATAN(COHESN/SIGGAH+TANPHI)	032500	0000
	PHIEQ=PHIEQR*180./PI	032510	0000
	IF(PHIEQ.GT.45.) PHIEQ=45.	032520	0000
C	-----	032530	0000
C	TUNNEL AND SHAFT LOADS	032540	0000
C	-----	032550	0000
C	ESTABLISH SEGMENT TYPE AND SHAPE FACTORS	032560	0000
	IF(SEGDEP.LE.2.8BE) GO TO 1300	032570	0000
	F=1.0	032580	0000
	FSHAPE=1.0	032590	0000
	IF(ITYPE.EQ.1) GO TO 1110	032600	0000
C	SHAFT SEGMENT	032610	0000
	F=0.5	032620	0000
	FSHAPE=0.5	032630	0000
	IF(ISHAPS.EQ.2) F=0.6	032640	0000
	IF(ISHAPS.EQ.2) FSHAPE=0.6	032650	0000
	GO TO 1200	032660	0000
C	TUNNEL SEGMENT	032670	0000
1110	IF(ISHAPE.EQ.3) FSHAPE=1.25	032680	0000
C	-----	032690	0000
1200	PSOIL=2.8BE*(GAMMA3+F*(SEGDEP-2.8BE))*(0.34-PHIEQ**2./6000.)*	032700	0000
	1 GAMMA3*FSHAPE	032710	0000
	GO TO 1310	032720	0000
1300	F=1.0	032730	0000
	IF(ITYPE.EQ.1) GO TO 1301	032740	0000
C	SHAFT SEGMENT	032750	0000
	F=0.5	032760	0000
	IF(ISHAPS.EQ.2) F=0.6	032770	0000
1301	PSOIL=SEGDEP*(GAMMAC+F	032780	0000
C	-----	032790	0000
1310	IF(LINUT.EQ.1) GO TO 1320	032800	0000
C	DRAINED	032810	0000
	PUATER=0	032820	0000
	GO TO 1330	032830	0000

(Continued)

COSTUN Listing (Continued)

C	WATERTIGHT	032840	0000
1320	PUATER=68.4*(ELWATR-ELAVG)	032850	0000
C	QUIT BELOW SEGMENT	032860	0000
	IF(PUATER.LT.0.) PUATER=0	032870	0000
1330	IF(ISUPPT.LE.3 .AND. TLIN.GT.TPLMIN) GO TO 1331	032880	0000
	PTOTAL=PSOIL+PUATER	032890	0000
	GO TO 2000	032900	0000
C	INPUT LINER THICKNESS GREATER THAN MINIMUM VALUE WILL BE CHECKED	032910	0000
C	FOR WATER PRESSURE	032920	0000
1331	PTOTAL=PUATER	032930	0000
C	IF PSOIL, PUATER, OR PTOTAL EQUAL 0, THEN ASSIGN A VALUE OF 0.001	032940	0000
C	FOR ESTIMATING SUPPORT SIZE	032950	0000
2000	IF(PSOIL.LT.0.001) PSOIL=0.001	032960	0000
	IF(PUATER.LT.0.001) PUATER=0.001	032970	0000
	IF(PTOTAL.LT.0.001) PTOTAL=0.001	032980	0000
C	-----	032990	0000
C	SUPPORT SIZE	033000	0000
C	-----	033010	0000
	GO TO(2100,2200,2300,2400),ISUPPT	033020	0000
C	CAST IRON SEGMENTED SUPPORT	033030	0000
2100	TPLATE=7.E-6*(BF**0.68)*PTOTAL**0.78	033040	0000
	GO TO 2350	033050	0000
C	PRECAST CONCRETE LINER	033060	0000
2200	IF(ITYPE.EQ.2) GO TO 2235	033070	0000
C	TUNNEL SEGMENT	033080	0000
	IF(ISHAPE=2) 2210,2220,2230	033090	0000
2210	TPLATE=1.55E-8*(0.1+0.046*(BF)*PTOTAL**1.6*EXP(SQRT((6.6-0.56*(LOG(PTOTAL)**2+0.016))))	033100	0000
	GO TO 2350	033110	0000
2220	TPLATE=2.6E-7*(0.1+0.044*(BF)*PTOTAL**1.38*EXP(SQRT((9.25-0.77*(LOG(PTOTAL)**2+0.048))))	033120	0000
	GO TO 2350	033130	0000
2230	TPLATE=6.5E-8*(0.1+0.044*(BF)*PTOTAL**1.48*EXP(SQRT((11.3-0.94*(LOG(PTOTAL)**2+0.21))))	033140	0000
	GO TO 2350	033150	0000
C	SHAFT SEGMENT	033160	0000
2235	IF(ISHAPS.EQ.1) GO TO 2210	033170	0000
	TPLATE=6.8E-7*(5.+4.7*(BF)*PTOTAL**0.93*EXP(SQRT((5.22-0.45*(LOG(PTOTAL)**2+0.08))))	033180	0000
	GO TO 2350	033190	0000
C	STEEL SEGMENTED SUPPORT	033200	0000
2300	IF(ITYPE.EQ.2) GO TO 2335	033210	0000
C	TUNNEL SEGMENT	033220	0000
	IF(ISHAPE=2) 2310,2320,2330	033230	0000
2310	TPLATE=6.95E-7*(BF**0.8)*PTOTAL**0.88	033240	0000
	GO TO 2350	033250	0000
2320	TPLATE=6.6E-4*(BF**0.74)*PTOTAL**0.39	033260	0000
	GO TO 2350	033270	0000
2330	TPLATE=8.5E-4*(BF**0.71)*PTOTAL**0.38	033280	0000
	GO TO 2350	033290	0000
C	SHAFT SEGMENT	033300	0000
2335	IF(ISHAPS.EQ.1) GO TO 2310	033310	0000
	TPLATE=0.001*(BF**0.75)*PTOTAL**0.38	033320	0000
2350	IF(TPLATE.LT.TPLMIN) TPLATE=TPLMIN	033330	0000
C	INPUT LINER THICKNESS GREATER THAN COMPUTED VALUE WILL BE USED	033340	0000
	IF(TPLATE.LT.TLIN) TPLATE=TLIN	033350	0000
	IF(TLIN.GE.TPLMIN .AND. TLIN.LT.TPLATE) MSTAKE=3	033360	0000
2354	TSEQ=FF*TPLATE	033370	0000
		033380	0000
		033390	0000
		033400	0000
		033410	0000

(Continued)

COSTUN Listing (Continued)

	IF(TSEG.LT.TSEGMN) TSEG=TSEGMN	033420	0000
	B1-BF+2.XTSEG	033430	0000
	IF(ITYPE.EQ.2) GO TO 2360	033440	0000
C	TUNNEL SEGMENT	033450	0000
	A(I,39)=BE	033460	0000
	A(I,40)=TPLATE	033470	0000
	A(I,11)=TSEG	033480	0000
	A(I,63)=PSOIL	033490	0000
	A(I,64)=PUATER	033500	0000
	A(I,65)=PTOTAL	033510	0000
	GO TO 2600	033520	0000
C	SHAFT SEGMENT	033530	0000
2360	B(I,29)=BE	033540	0000
	B(I,41)=TPLATE	033550	0000
	B(I,11)=TSEG	033560	0000
	B(I,38)=PSOIL	033570	0000
	B(I,43)=PUATER	033580	0000
	B(I,31)=PTOTAL	033590	0000
	GO TO 2600	033600	0000
C	STEEL RIB WITH LINING	033610	0000
C	LINING THICKNESS	033620	0000
C	FOR CUT-AND-COVER SHAFT CONCRETE LINING IS TO RESIST PSOIL+PUATER.	033630	0000
C	WHEN INPUT LINING GREATER THAN 8 IN., THICKNESS IS CHECKED FOR	033640	0000
C	WATER PRESSURE ONLY	033650	0000
2400	IF(ICUTNC.EQ.1 .AND. TLIN.LT.0.666) PUATER=PSOIL+PUATER	033660	0000
	IF(ITYPE.EQ.2) GO TO 2435	033670	0000
C	TUNNEL SEGMENT	033680	0000
	IF(ISHAPE-2) 2410,2420,2430	033690	0000
2410	TL=0.5XBFXPUATER/(288000.-PUATER)	033700	0000
	GO TO 2445	033710	0000
2420	TL=0.77E-10XBFXX0.86XPUATERXX1.9XEXP(SQRT((16.9-1.42XALOG(PUATER)))	033720	0000
	1XX2+0.32))	033730	0000
	GO TO 2445	033740	0000
2430	TL=3.8E-7X(7.+4.6XBF)XPUATERXX1.035XEXP(SQRT((6.5-0.565XALOG	033750	0000
	1(PUATER))XX2+0.17))	033760	0000
	GO TO 2445	033770	0000
C	SHAFT SEGMENT	033780	0000
2435	IF(ISHAPS.EQ.1) GO TO 2410	033790	0000
	TL=3.6E-5X(7.+4.6XBF)XPUATERXX0.68XEXP(SQRT((2.-0.185XALOG(PUATER)	033800	0000
	1)XX2+0.04))	033810	0000
2445	IF(TL.LT.TLMIN) TL=TLMIN	033820	0000
C	INPUT LINING THICKNESS GREATER THAN COMPUTED VALUE WILL BE USED	033830	0000
	IF(TL.LT.TLMIN) TL=TLIN	033840	0000
	IF(TLIN.GE.TLMIN .AND. TLIN.LT.TL) NSTAKE=3	033850	0000
	IF(ICUTNC.EQ.0) GO TO 2500	033860	0000
	UEB=0	033870	0000
	GO TO 2545	033880	0000
2500	B1-BF+2.XTL	033890	0000
C	STEEL RIB SIZE	033900	0000
	IF(ITYPE.EQ.2) GO TO 2535	033910	0000
	IF(ISHAPE-2) 2510,2520,2530	033920	0000
C	TUNNEL SEGMENT	033930	0000
2510	UEB=0.0115XB1XX0.39XPSOILXX0.33	033940	0000
	GO TO 2540	033950	0000
2520	UEB=0.066XB1XX0.76X(PSOIL/1000.)XX(0.6XB1XX(-0.3))	033960	0000
	GO TO 2540	033970	0000
2530	UEB=0.067XB1XX0.78X(PSOIL/1000.)XX(0.565XB1XX(-0.29))	033980	0000
	GO TO 2540	033990	0000

(Continued)

COSTUN Listing (Continued)

C	SHAFT SEGMENT	034000 0000
2536	IF(ISHAPE.EQ.1) GO TO 2510	034010 0000
	UEB=0.1X1370.7X(PSOIL/1000.)XX(0.305-0.0027XB1)	034020 0000
2540	IF(UEB.LT.0.5) UEB=0.5	034030 0000
2546	BE=BF+2.XTL+2.XUEB	034040 0000
	IF(ITYPE.EQ.2) GO TO 2550	034050 0000
	A(I,30)=BE	034060 0000
	A(I,62)=UEB	034070 0000
	A(I,11)=TL	034080 0000
	A(I,63)=PSOIL	034090 0000
	A(I,64)=PWATER	034100 0000
	A(I,65)=PTOTAL	034110 0000
	GO TO 2600	034120 0000
2550	B(I,29)=BE	034130 0000
	B(I,41)=UEB	034140 0000
	B(I,11)=TL	034150 0000
	B(I,30)=PSOIL	034160 0000
	B(I,43)=PWATER	034170 0000
	B(I,31)=PTOTAL	034180 0000
C	CHECK IF INPUT THICKNESS ACCEPTED WHEN WATER PRESSURE=0	034190 0000
2600	IF(I2.EQ.1) GO TO 4000	034200 0000
C	CHECK IF ASSUMED 'BE' IS WITHIN ONE PERCENT OF COMPUTED 'BE'	034210 0000
	IF(BE/BBEE.LT.0.99 .OR. BE/BBEE.GT.1.01) GO TO 1000	034220 0000
	IF(ITYPE.EQ.2) GO TO 2605	034230 0000
	IF(MSTAKE.EQ.1) WRITE(LO,1010) NTSEG,NREACH	034240 0000
	IF(MSTAKE.EQ.3) WRITE(LO,2710) NTSEG,NREACH	034250 0000
	GO TO 4000	034260 0000
2605	IF(MSTAKE.EQ.1) WRITE(LO,1011) NSSEG,NSHAFT	034270 0000
	IF(MSTAKE.EQ.3) WRITE(LO,2711) NSSEG,NSHAFT	034280 0000
	GO TO 4000	034290 0000
C		034300 0000
C		034310 0000
C		034320 0000
C		034330 0000
C	*****	034340 0000
C	CUT AND COVER ONLY	034350 0000
C	*****	034360 0000
C		034370 0000
C		034380 0000
C	DATA	034390 0000
C		034400 0000
2900	IF(ITYPE.EQ.2) GO TO 3300	034410 0000
	ELROCK=A(I,27)	034420 0000
	ELIMP=A(I,24)	034430 0000
	D10=A(I,19)	034440 0000
	PERM=A(I,25)	034450 0000
	DROCK=ELSURF-ELROCK	034460 0000
	NBOX=TRDATA(NREACH,10)	034470 0000
	BFBUDT=TRDATA(NREACH,11)	034480 0000
	BFBHT=TRDATA(NREACH,12)	034490 0000
	IBOX2=TRDATA(NREACH,13)	034500 0000
	IDECK=A(I,29)	034510 0000
	IBRACE=A(I,28)	034520 0000
	DTUN=ELSURF-ELAUG	034530 0000
	IF(IBOX2.EQ.1) GO TO 3000	034540 0000
	BOXUDT=BFBUDT/NBOX	034550 0000
	BOXHT=BFBHT	034560 0000
	GO TO 3001	034570 0000

(Continued)

COSTUN Listing (Continued)

3000	BOXWDT=BFBDWT/2.	034580	0000
	BOXHT=BFBDHT/2.	034590	0000
	NBOX=8	034600	0000
3001	SURGE=400.	034610	0000
	TROOF=0.0	034620	0000
	TINUT=0.0	034630	0000
	TINSB=0.0	034640	0000
	TINUL=0.0	034650	0000
	TEXUL=0.0	034660	0000
	UTROOF=0.0	034670	0000
	UTINSB=0.0	034680	0000
	K=0	034690	0000
C	-----	034700	0000
3002	DTRNCH=DTUN+BFBDHT/2+TINUT+TINSB/2.	034710	0000
	DSOIL=DTRNCH	034720	0000
	IF(DROCK.LT.DTRNCH) DSOIL=DROCK	034730	0000
	TOTBOX=BFBDHT+TINUT+TROOF+TINSB	034740	0000
	DROOF=DTRNCH-TOTBOX	034750	0000
	UATPRI=0	034760	0000
	UATPRR=0	034770	0000
	IF(DUATER.GE.DTRNCH) GO TO 3005	034780	0000
	UATPRI=62.4*(DTRNCH-DUATER)	034790	0000
	IF(DUATER.LT.DROOF) UATPRR=UATPRI-62.4*TOTBOX	034800	0000
C	-----	034810	0000
C	TRENCH PRESSURE FOR SUPPORTS	034820	0000
C	-----	034830	0000
3005	SIGMAT=GAMMA*DSOIL	034840	0000
	SIGMA1=GAMMA*DSOIL	034850	0000
	IWATER=A(I,23)	034860	0000
	STABNO=A(I,30)	034870	0000
	IF(DUATER.LT.DSOIL.AND.IWATER.EQ.0) SIGMA1=GAMMA*DUATER+(GAMMA-	034880	0000
	162.4)*(DSOIL-DUATER)	034890	0000
	IF(STABNO.LT.0.01) STABNO=(SIGMAT+SURGE)/(COHESN+(SIGMA1+SURGE)/2.	034900	0000
	1*(1-SIN(PHI*PI/180.))*TAN(PHI*PI/180.))	034910	0000
	IF(IISUPPT.EQ.5.OR.MEX.EQ.7) GO TO 3010	034920	0000
C	SLURRY WALL TRENCH SUPPORT	034930	0000
	TRENPR=0.3*SIGMAT	034940	0000
	IF(IWATER.EQ.1.AND.D10.GT.0.005) GO TO 3025	034950	0000
	IF(DUATER.LT.DSOIL) TRENPR=0.3*(GAMMA*DUATER**2.+(GAMMA-62.4)*	034960	0000
	1*(DSOIL-DUATER)**2.+2.*GAMMA*DUATER*(DSOIL-DUATER)+2.*62.4*(DSOIL-	034970	0000
	2*DUATER)**2.)/DSOIL	034980	0000
	GO TO 3025	034990	0000
C	SOLDIER PILE / LAGGING TRENCH SUPPORT	035000	0000
3010	TEMP1=0.6*(GAMMA*DSOIL*(TAN(PI/180.*X(45.-PHI/2.))**2.	035010	0000
	TEMP2=2.4*COHESN*TAN(PI/180.*X(45.-PHI/2.))	035020	0000
	IF(STABNO.LE.4) GO TO 3015	035030	0000
	TM=1.1-0.1*STABNO	035040	0000
	IF(TM.LT.0.4) TM=0.4	035050	0000
	TRENPR=TEMP1*(PHI+0.83)/(PHI+0.62)-TEMP2*(PHI+0.83)/(PHI+0.62)*TM	035060	0000
	GO TO 3020	035070	0000
3015	TRENPR=TEMP1*(PHI+0.14)/(PHI+0.35)-TEMP2*PHI/(PHI+0.2)	035080	0000
3020	IF(TRENPR.LT.0.0) TRENPR=0.0	035090	0000
C	-----	035100	0000
C	EARTH PRESSURE FOR BOX MEMBERS	035110	0000
3025	ERTHPR=0.5*(GAMMA*DTUN	035120	0000
C	-----	035130	0000
C	THICKNESS OF BOX MEMBERS	035140	0000
C	-----	035150	0000

(Continued)

COSTUN Listing (Continued)

	ULTCOM=5.0*10.**3.	035160	0000
	ALLCOM=0.45*ULTCOM	035170	0000
	AXIALW=0.0	035180	0000
	AXIALS=0.0	035190	0000
	PSOIL=ERTHPR+SURGE	035200	0000
	J=0	035210	0000
C	SOIL AND WATER LOADS ON BOX MEMBERS	035220	0000
C	INPUT THICKNESS WILL NOT BE USED	035230	0000
	IF(TLIN.GT.0.0) WRITE(LO,3500) NTSEG,NREACH	035240	0000
C	-----	035250	0000
C	AXIAL LOAD AND UNIFORM LOADS	035260	0000
	J=J+1	035270	0000
3030	GO TO (3040,3050,3060,3070,3080),J	035280	0000
C	ROOF SLAB	035290	0000
3040	PTOTAL=GAMMA*DROOF/1.1+WTROOF+SURGE	035300	0000
	GO TO 3052	035310	0000
3050	TROOF=THICK/12.	035320	0000
	WTROOF=150.*TROOF	035330	0000
C	INVERT SLAB	035340	0000
	PWATER=WATPRI-WATPRR	035350	0000
	PTOTAL=PTOTAL+PWATER	035360	0000
3052	IF(WATPRI.EQ.0.0) GO TO 3055	035370	0000
	IF(WATPRR.GT.0.0) AXIALW=0.25*BOXHT*(WATPRI+WATPRR)	035380	0000
	IF(WATPRR.EQ.0.0) AXIALW=0.25*BOXHT*WATPRI*(DTRNCH-DWATER)/TOTBOX	035390	0000
3055	IF(DROCK.GE.DTRNCH) GO TO 3057	035400	0000
	IF(DROCK.LE.DROOF) GO TO 3058	035410	0000
	PSOIL=PSOIL*(DROCK-DROOF)/TOTBOX	035420	0000
3057	AXIALS=0.5*PSOIL*BOXHT	035430	0000
3058	AXIAL=AXIALW+AXIALS	035440	0000
	SPANL=BOXWDT	035450	0000
	GO TO 3100	035460	0000
3060	TINUT=THICK/12.	035470	0000
C	INTERIOR SLAB	035480	0000
	IF(BOX2.EQ.1) GO TO 3062	035490	0000
	THICK=0.0	035500	0000
	GO TO 3030	035510	0000
3062	PTOTAL=400.+WTINSB	035520	0000
	IF(WATPRI.EQ.0.0) GO TO 3065	035530	0000
	AXIALW=2.0*AXIALW	035540	0000
3065	IF(DROCK.LE.DROOF) GO TO 3067	035550	0000
	AXIALS=2.0*AXIALS	035560	0000
3067	AXIAL=AXIALS+AXIALW	035570	0000
	SPANL=BOXWDT	035580	0000
	GO TO 3100	035590	0000
3070	TINSB=THICK/12.	035600	0000
	WTINSB=150.*TINSB	035610	0000
	K=K+1	035620	0000
	IF(K.EQ.1) GO TO 3002	035630	0000
C	INTERIOR WALL	035640	0000
	AXIAL=(GAMMA*DROOF/1.1+SURGE+WTROOF+WTINSB+400.)*BOXWDT	035650	0000
	SPANL=BOXHT	035660	0000
	IF(NBOX.GT.1) GO TO 3105	035670	0000
	THICK=0.0	035680	0000
	GO TO 3030	035690	0000
3080	TINWL=THICK/12.	035700	0000
C	EXTERIOR WALL	035710	0000
	AXIAL=AXIAL/2.	035720	0000
	SPANL=BOXHT	035730	0000

(Continued)

COSTUN Listing (Continued)

	IF(DWATER.GE.DTRNCH.AND.ISUPPT.EQ.6.)GO TO 3105	035740	0000
	IF(ISUPPT.EQ.6.OR.DROCK.LE.DROCF) P5OIL=0.0	035750	0000
	PWATER=0.0	035760	0000
	IF(WATPRI.EQ.0.0) GO TO 3085	035770	0000
	IF(WATPRR.GT.0.0) PWATER=(WATPRI+WATPRR)/2.	035780	0000
	IF(WATPRR.EQ.0.0) PWATER=0.5*WATPRI*(DTRNCH-DWATER)/TOTBOX	035790	0000
3085	PTOTAL=P5OIL+PWATER	035800	0000
C	-----	035810	0000
C	THICKNESS COMPUTATION	035820	0000
3100	MOMENT=0.1*PTOTAL*SPANL**2.	035830	0000
	THICK=AXIAL/(24.*ALLCOM)+SQRT((AXIAL/(12.*ALLCOM))**2.+24.*MOMENT/	035840	0000
	1ALLCOM)/2.	035850	0000
	GO TO 3110	035860	0000
3105	THICK=AXIAL/18800.	035870	0000
C	COSTUN MINIMUM	035880	0000
3110	IF(THICK.LT.8.0) THICK=8.0	035890	0000
C	ACI REQUIREMENT	035900	0000
	IF(THICK.LT.SPANL*12./25.) THICK=12.*SPANL/25.	035910	0000
	IF(J.LT.5) GO TO 3030	035920	0000
	TEXUL=THICK/12.	035930	0000
C	-----	035940	0000
C	FINAL OVERALL BOX DIMENSIONS	035950	0000
	TOTBOX=BFBHT+TROOF+TINUT+TINSB	035960	0000
	WDTBOX=BFBWDT+2.*TEXUL+(NBOX-1)*TINUL	035970	0000
	BE=WDTBOX	035980	0000
C	FINAL TRENCH DEPTH	035990	0000
	DTRNCH=DTUN+BFBHT/2.+TINUT+TINSB/2.	036000	0000
	DSOIL=DTRNCH	036010	0000
	IF(DROCK.LT.DTRNCH) DSOIL=DROCK	036020	0000
	DROOF=DTRNCH-TOTBOX	036030	0000
	CONSTR=6.0	036040	0000
	IF(DROCK.GT.DROOF.AND.ISUPPT.NE.6) BE=BE+CONSTR	036050	0000
C	INITIALIZE	036060	0000
	WTUALE=0.	036070	0000
	WTSTRT=0.	036080	0000
	WTANCH=0.	036090	0000
	WTSP=0.	036100	0000
	WTSPD=0.	036110	0000
	SPDLT=0.	036120	0000
	DSP=0.	036130	0000
	DSPD=0.	036140	0000
	SIDSL=0.	036150	0000
	DSLURY=0.0	036160	0000
	IF(MEX.EQ.7) GO TO 3140	036170	0000
	IF(DROCK.LT.0.1) GO TO 3190	036180	0000
	IF(ISUPPT.EQ.5) GO TO 3120	036190	0000
C	-----	036200	0000
C	SLURRY WALL SUPPORT SYSTEM	036210	0000
C	-----	036220	0000
C	COMPUTE LENGTH OF SLURRY WALL	036230	0000
	IS ROCK LINE ABOVE TRENCH BOTTOM	036240	0000
	IF(DROCK.LT.DTRNCH) GO TO 3117	036250	0000
C	IS ROCK LINE SHALLOWER THAN 8 FT BELOW TRENCH	036260	0000
	IF(DROCK.LT.DTRNCH+8.) GO TO 3116	036270	0000
C	IS GROUNDWATER TABLE BELOW TRENCH BOTTOM	036280	0000
	IF(DWATER.GT.DTRNCH) GO TO 3115	036290	0000
	IF(IWATER.EQ.1 .AND. D10.GT.0.005) GO TO 3115	036300	0000
	IF(D10.GT.0.005) GO TO 3112	036310	0000

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COSTUM Listing (Continued)

C	WEIGHTED CREEP RATIO DETERMINES SLURRY WALL PENETRATION	036320	0000
	CREPMN=(340.+1.55*COHESN)/COHESN	036330	0000
	GO TO 3113	036340	0000
3118	CREPMN=4.3-1.8*ALOG10(SQRT(10.*ABS(PERM)))	036350	0000
3113	DSLURY=DTRNCH+10.	036360	0000
	CREEP=(2.*DSLURY-DWATER-DTRNCH)/(DTRNCH-DWATER)	036370	0000
	IF(CREEP.GT.CREPMN) GO TO 3120	036380	0000
	DSLURY=(CREPMN*(DTRNCH-DWATER)+DWATER+DTRNCH)/2.	036390	0000
	DTIMP=ELSURF-ELIMP	036400	0000
	IF(DTIMP.GE.DSLURY.OR.D10.LE.0.005) GO TO 3114	036410	0000
C	SLURRY WALL PENETRATES IMPERVIOUS LAYER	036420	0000
	H1=DTIMP-DWATER	036430	0000
	IF(H1.LT.0.) H1=0.	036440	0000
	H2=DTIMP-DTRNCH	036450	0000
	H2DN=H2	036460	0000
	H2UP=DTRNCH-DTIMP	036470	0000
	IF(DTIMP.GE.DTRNCH) H2UP=0.	036480	0000
	IF(DTIMP.LT.DTRNCH) H2DN=0.	036490	0000
	AA=4.	036500	0000
	BB=4.*ABS(H2)+4*H2	036510	0000
	CC=H1**2.+H2**2.+2.*H1*ABS(H2)+2.*H2UP*(H2-H1)+CREPMN*(H2-H1)*	036520	0000
	1*(H2DN+H1)	036530	0000
	PENIMP=(-BB+SQRT(BB**2.-4.*AA*CC))/2./AA	036540	0000
	IF(DTIMP.GE.DTRNCH) DSLURY=DTIMP+PENIMP	036550	0000
	IF(DTIMP.LT.DTRNCH) DSLURY=DTRNCH+PENIMP	036560	0000
C	MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN SOIL	036570	0000
	IF(DSLURY.LT.DTRNCH+10.) DSLURY=DTRNCH+10.	036580	0000
3114	IF(DSLURY.GT.DROCK+2.) DSLURY=DROCK+2.	036590	0000
	GO TO 3120	036600	0000
C	MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN SOIL	036610	0000
3115	DSLURY=DTRNCH+10.	036620	0000
	GO TO 3120	036630	0000
C	MINIMUM EMBEDMENT FOR ALL SLURRY WALLS IN ROCK	036640	0000
3116	DSLURY=DROCK+2.	036650	0000
	GO TO 3120	036660	0000
C	IS ROCK LINE AT LEAST 2 FT ABOVE ROOF OF BOX	036670	0000
3117	IF(DROCK+2..LT.DROOF) GO TO 3118	036680	0000
	DSLURY=DTRNCH+2.	036690	0000
	GO TO 3120	036700	0000
3118	DSLURY=DROCK+2.	036710	0000
	-----	036720	0000
C	SOLDIER PILE/LAGGING SUPPORT SYSTEM	036730	0000
	-----	036740	0000
3120	TRENPR=TRENPR+SURGE	036750	0000
C	ANCHORS AND/OR STRUTS	036760	0000
	WTSTRT=0.0225*TRENPR+0.8*BE	036770	0000
	ANCHDI=0.94*SQRT(TRENPR/1000.)	036780	0000
	IF(ANCHDI.LT.0.5) ANCHDI=0.5	036790	0000
	WTANCH=PI*(ANCHDI/2.)*2.*0.283*12.	036800	0000
	IF(IBRACE.EQ.1) WTANCH=0.	036810	0000
	IF(IBRACE.EQ.2) WTSTRT=0.	036820	0000
	IF(ISUPPT.EQ.6) GO TO 3190	036830	0000
C	WALES	036840	0000
	UTWALE=SQRT(5.6*TRENPR)	036850	0000
	IF(UTWALE.LT.13.) UTWALE=13.	036860	0000
	DWALE=SQRT(8.*UTWALE)-5.0	036870	0000
C	SOLDIER PILES	036880	0000
C	NON DECKED SOLDIER PILES	036890	0000

(Continued)

COSTEN Listing (Continued)

	UTSP = SQRT(TRENPR)	036900 0000
	IF(UTSP.LT.13.) UTSP=13.	036910 0000
	DSP=SQRT(6.*UTSP)-5.0	036920 0000
	IF(IDECK.EQ.0) GO TO 3125	036930 0000
C	DECKED SOLDIER PILES	036940 0000
	SPAXAL=15.*BE/2.*400.	036950 0000
	UTSPD=SQRT(TRENPR)+0.222*SPAXAL/1000.*(1.0-0.25*(TRENPR/1000.))	036960 0000
	1*(2.333)	036970 0000
	IF(UTSPD.LT.13.) UTSPD=13.	036980 0000
	DSPD=SQRT(6.*UTSPD)-5.0	036990 0000
C	IS ROCK LINE ABOVE TRENCH BOTTOM	037000 0000
	IF(DROCK.LE.DTRNCH) GO TO 3124	037010 0000
	DPILEH=1./6.*SQRT(1.5*UTSPD)	037020 0000
	IF(PHI.GT.0.) GO TO 3122	037030 0000
	SPDLT=DTRNCH+(1.75*SPAXAL/(0.5*PI*DPILEH))-6.7*COHESN*DPILEH/2.)/	037040 0000
	1(2.*COHESN*DPILEH/2.*GAMMA)	037050 0000
	GO TO 3123	037060 0000
3122	CNQ=EXP(PI*TAN(PHI*PI/180.))*TAN(PI/4.+PHI*PI/360.))*2	037070 0000
	CNC=(CNQ-1.)/TAN(PHI*PI/180.)	037080 0000
	IF(PHI.GT.0.) CNGAM=0.	037090 0000
	IF(PHI.GT.10.) CNGAM=0.3*(PHI-10.)	037100 0000
	IF(PHI.GT.20.) CNGAM=(PHI*2-335.)/22.3	037110 0000
	IF(PHI.GT.35.) CNGAM=8.*(PHI-35.)/40.	037120 0000
	IF(PHI.GT.40.) CNGAM=32.*(PHI-40.)/80.	037130 0000
	AA=GAMMA*TAN(PHI*PI/180.)	037140 0000
	BB=2.*COHESN*DPILEH/2.*GAMMA*CNC	037150 0000
	CC=1.3*COHESN*DPILEH/2.*CNC+0.6*GAMMA*(0.5*DPILEH))*2*CNGAM	037160 0000
	1-1.75*SPAXAL/(0.5*PI*DPILEH)	037170 0000
	SPDLT=DTRNCH+((-BB+SQRT(BB*2-4.*AA*CC))/(2.*AA)	037180 0000
3123	IF(SPDLT.LT.DTRNCH+10.) SPDLT=DTRNCH+10.	037190 0000
	IF(SPDLT.GT.DROCK+2.) SPDLT=DROCK+2.	037200 0000
	GO TO 3125	037210 0000
3124	SPDLT=DTRNCH+2.	037220 0000
C	-----	037230 0000
C	FOR ROCK DESIGN, CHECK IF EXTERIOR BOX WALL IS SMALLER THAN DEPTH	037240 0000
C	OF SOLDIER PILE EMBEDDED IN WALL	037250 0000
3125	IF(DROCK.GT.DROOF) GO TO 3130	037260 0000
	IF(DROCK+10..GT.DROOF.AND.TEXTUL.LT.DSP/12.) TEXTUL=DSP/12.	037270 0000
	IF(TEXTUL.LT.DSPD/12.) TEXTUL=DSPD/12.	037280 0000
C	-----	037290 0000
C	IN ROCK, EXCAVATED TRENCH WIDTH EQUALS BOX WIDTH	037300 0000
	WDTBOX=8*BWDT+2*TEXTUL*(NBOX-1)*TINWL	037310 0000
	BE=WDTBOX	037320 0000
	GO TO 3190	037330 0000
C	-----	037340 0000
C	COMPUTE FINAL EXCAVATED TRENCH WIDTH FOR BOX IN SOIL	037350 0000
3130	IF(IDECK.EQ.0) BE=BE+(2.*DUALE+2.*DSP)/12.	037360 0000
	IF(IDECK.EQ.1) BE=BE+(2.*DUALE+2.*DSPD)/12.	037370 0000
	GO TO 3190	037380 0000
C	-----	037390 0000
C	SIDE SLOPE FOR OPEN CUTS IN SOIL	037400 0000
C	-----	037410 0000
C	ALL SLOPING CUTS EXCEPT CLAYS (D10.LE.0.005) WILL BE DEWATERED	037420 0000
3140	IF(COHESN.GT.0.0) GO TO 3150	037430 0000
C	MATERIALS CHARACTERIZED BY PHI ONLY	037440 0000
	SIDESL=1.25/TAN(PHI*PI/180.)	037450 0000
	GO TO 3190	037460 0000
C	MATERIALS CHARACTERIZED BY COHESION ONLY OR BY PHI AND COHESION	037470 0000

(Continued)

COSTUN Listing (Continued)

3160	SIGGAH=GAMMA*DSOIL	037480	0000
	IF(DWATER.LT.DSOIL.AND.D10.LE.0.005) SIGGAH=GAMMA*DWATER+(GAMMA-	037490	0000
	162.4)*(DSOIL-DWATER)	037500	0000
	PHIDEV=ATAN(TAN(PHI*PI/180.)/1.25)	037510	0000
	SIDESL=0.577	037520	0000
	TEMP1=(1.0-COS(ATAN(1./SIDESL)-PHIDEV))/(4.*SIN(ATAN(1./SIDESL)))	037530	0000
	1xCOS(PHIDEV))	037540	0000
	TEMP2=COESN/(1.25*SIGGAH)	037550	0000
	IF(TEMP1.LE.TEMP2) GO TO 3190	037560	0000
C	-----	037570	0000
C	SLOPE ANGLE IS BETWEEN PHIDEV AND 60 DEGREES	037580	0000
	IF(PHI.EQ.0.0) MAX=11.0	037590	0000
	IF(PHI.GT.0.0) MAX=1/TAN(PHIDEV)	037600	0000
	MIN=0.577	037610	0000
C	ITERATION REQUIRED TO DETERMINE DESIGN SLOPE	037620	0000
3160	SIDESL=(MIN+MAX)/2.	037630	0000
	TEMP1=(1.0-COS(ATAN(1./SIDESL)-PHIDEV))/(4.*SIN(ATAN(1./SIDESL)))	037640	0000
	1xCOS(PHIDEV))	037650	0000
	IF(TEMP1.GT.TEMP2) GO TO 3170	037660	0000
	MIN=SIDESL	037670	0000
	IF(MAX-MIN.LE.0.01) GO TO 3180	037680	0000
	GO TO 3160	037690	0000
3170	MAX=SIDESL	037700	0000
	IF(MAX-MIN.LE.0.01) GO TO 3180	037710	0000
	GO TO 3160	037720	0000
3180	SIDESL=(MIN+MAX)/2.	037730	0000
C	-----	037740	0000
C	SUMMARY CUT AND COVER	037750	0000
C	-----	037760	0000
C	VOLUME DISPLACED BY BOX	037770	0000
3190	UBOX=TOTBOX*WDTBOX/27.	037780	0000
C	-----	037790	0000
C	TOTAL VOLUME OF CONCRETE PER FOOT OF BOX	037800	0000
	UL=(WDTBOX*(TROOF+TINUT+TINSB)+BFBHT*(2*TEXUL+(NBOX-1)*TINUL))/27.	037810	0000
C	-----	037820	0000
C	FORMWORK FOR CAST IN PLACE CONCRETE	037830	0000
	FORMAR=0.	037840	0000
	IF(LINING.NE.1) GO TO 3200	037850	0000
	FORMAR=BFBHT*(2+(NBOX-1)*2)+BFBWDT	037860	0000
	IF(ISUPPT.EQ.5.AND.DROCK.GT.DROOF) FORMAR=FORMAR+2.*TOTBOX	037870	0000
	IF(IBOX2.EQ.1) FORMAR=FORMAR+BFBWDT	037880	0000
C	-----	037890	0000
C	STORE TRANSFERED VALUES IN 'A' ARRAY	037900	0000
C	-----	037910	0000
3200	A(I,30)=STABNO	037920	0000
	IF(ISUPPT.EQ.5) A(I,38)=SPDLT	037930	0000
	IF(ISUPPT.EQ.6) A(I,38)=DSLURY	037940	0000
	A(I,39)=BE	037950	0000
	BOB=BE	037960	0000
	A(I,42)=BOB	037970	0000
	A(I,43)=TOTBOX	037980	0000
	A(I,52)=DTRNCH	037990	0000
	A(I,53)=SIDESL	038000	0000
	A(I,54)=UBOX	038010	0000
	A(I,55)=UL	038020	0000
	A(I,56)=FORMAR	038030	0000
	A(I,63)=UTUALE	038040	0000
	A(I,64)=UTSTRT	038050	0000

(Continued)

COSTUN Listing (Continued)

	A(I,65)=UTANCH	038060	0000
	A(I,66)=UTSP	038070	0000
	A(I,67)=UTSPD	038080	0000
	GO TO 4000	038090	0000
C	-----	038100	0000
C	CUT AND COVER SHAFTS	038110	0000
C	-----	038120	0000
3300	ICUTNC=1	038130	0000
	ISUPPT=4	038140	0000
	LINING=1	038150	0000
C	REDUCE UNIT WEIGHT OF SOIL DUE TO BULKING DURING BACKFILLING	038160	0000
	GAMMA=GAMMA/1.1	038170	0000
	GO TO 1000	038180	0000
4000	CONTINUE	038190	0000
	IF(NSSTYP.EQ.3.OR.NTSTYP.EQ.3) RETURN	038200	0000
C	CHECK IF FACE INFLOW INPUT WHEN GROUND WATER TABLE BELOW SEGMENT	038210	0000
	GI=A(I,9)	038220	0000
	ELAUG=(ELNPL+ELNPR)/2.	038230	0000
	BE=A(I,39)	038240	0000
	ELBOTM=ELAUG-BE/2.	038250	0000
	IF(ISHAPE.EQ.3) ELBOTM=ELAUG-BE/4.	038260	0000
	IF(ITYPE.EQ.1.AND.GI.GT.0.0.AND.ELBOTM.GE.ELWATR) WRITE(LO,3600)	038270	0000
	1NTSEG,NREACH	038280	0000
C	-----	038290	0000
C	CHECK IF SHAFT SEGMENT IS WET WHEN WATER TABLE IS BELOW SEGMENT	038300	0000
	GI=B(I,9)	038310	0000
	IF(ITYPE.EQ.2.AND.GI.GT.0.0.AND.ELNPR.GT.ELWATR) WRITE(LO,3605)	038320	0000
	1NSSEG,NSHAFT	038330	0000
	RETURN	038340	0000
C	-----	038350	0000
5000	PWATER=62.4*(ELWATR-ELAUG)		
	IF(PWATER.LE.0.001)PWATER=.001		
	TL=TLIN		
	BF=BF+2*TL+.333		
	BE40=BE		
	BE60=BE		
	BOB=BE		
	BOB40=BOB		
	BOB60=BOB		
	A(I,39)=BE		
	A(I,40)=BE40		
	A(I,41)=BE60		
	A(I,42)=BOB		
	A(I,43)=BOB40		
	A(I,44)=BOB60		
	A(I,64)=PWATER		
	A(I,11)=TL		
C	*****	038370	0000
1010	FORMAT(/, ' *** WARNING *** ---THICKNESS INPUTED FOR SEGMENT',	038380	0000
	1 I4, ' IN REACH', I4, ' IS LESS THAN IN STANDARD DESIGN. INPUT IGN		
	20RED')	038400	0000
1011	FORMAT(/, ' *** WARNING *** ---THICKNESS INPUTED FOR SEGMENT',	038410	0000
	1 I4, ' IN SHAFT', I4, ' IS LESS THAN IN STANDARD DESIGN. INPUT IGN	038420	0000
	20RED')	038430	0000
2710	FORMAT(/, ' *** WARNING *** ---THICKNESS INPUTED FOR SEGMENT', I4	038440	0000
	1, ' IN REACH', I4, ' APPEARS TO BE INADEQUATE FOR WATER PRESSURE.	038450	0000
	2, ' COMPUTED THICK. FOR WATER PRESSURE USED')	038460	0000
2711	FORMAT(/, ' *** WARNING *** ---THICKNESS INPUTED FOR SEGMENT', I4	038470	0000

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COSTUN Listing (Continued)

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1, ' IN SHAFT', I4, ' APPEARS TO BE INADEQUATE FOR WATER PRESSURE. 038480 0000
2, ' COMPUTED THICK. FOR WATER PRESSURE USED' ) 038490 0000
3500 FORMAT(/IX, '**** REMINDER **** A LINING THICKNESS WAS INPUT FOR 038500 0000
1 A CUT AND COVER BOX IN SEGMENT', I4, ' IN REACH', I4, '. INPUT IGNOR 038510 0000
2ED' ) 038520 0000
3600 FORMAT(/, '**** WARNING **** A GROUND WATER INFLOW WAS SPECIFIC 038530 0000
1D IN SEGMENT', I5, ' IN REACH', I5, ' WHEN WATER TABLE IS BELOW BASE O 038540 0000
2F TUNNEL.' ' INFLOW IGNORED IN COST COMPUTATIONS.' ) 038550 0000
3605 FORMAT(/, '**** WARNING **** WET GROUND SPECIFIED IN SEGMENT', 038560 0000
1I5, ' IN SHAFT', I5, ' WHEN WATER TABLE IS BELOW SEGMENT.' ' WET GROU 038570 0000
2ND IGNORED IN COST COMPUTATIONS.' ) 038580 0000
***** 038590 0000
C 038600 0000
C 038610 0000
C 038615 0000
RETURN 038620 0000
END 038630 0000
SUBROUTINE STABIL(I,A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX 038635
1,NTRMAX) 038640 0000
----- 038650 0000
C 038660 0000
CC THIS SUBROUTINE SELECTS THE STABILITY NUMBER, STABILIZATION METHOD, 038670 0000
C AND EXCAVATION METHOD TO BE USED IN SOFT GROUND TUNNEL AND SHAFT 038680 0000
C SEGMENTS 038690 0000
----- 038700 0000
C 038710 0000
COMMON /BASIC/ NSS,NTS 038720 0000
COMMON /A/ LO,LI,PH,OM,LIST(40),TITLE(160),STABEG,ITYPE 038730 0000
COMMON /F/ IERROR,ISTOP 038740 0000
DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 038750 0000
1 TRDATA(NTRMAX,23) 038760 0000
----- 038770 0000
C 038780 0000
CC DO NOT COMPUTE A STABILITY NUMBER IF ONE WAS INPUT. ALSO, DO NOT 038790 0000
C COMPUTE ONE FOR PORTALS, DUMMY SHAFTS, AND CUT-AND-COVER SEGMENTS. 038800 0000
IF(ITYPE.EQ.1) GO TO 1000 038810 0000
----- 038820 0000
C 038830 0000
CC THIS IS A SHAFT SEGMENT 038840 0000
C CHECK FOR ROCK OR CUT AND COVER SEGMENTS AND FOR A PORTAL OR 038850 0000
C A DUMMY SHAFT 038860 0000
NSSTYP=B(I,15) 038870 0000
IF(NSSTYP.EQ.1) GO TO 500 038880 0000
IF(NSSTYP.EQ.3) RETURN 038890 0000
NSHAFT=B(I,1) 038900 0000
NPORT=SHAFT(NSHAFT,23) 038910 0000
IF(NPORT.EQ.1) RETURN 038920 0000
ISHAPS=SHAFT(NSHAFT,16) 038930 0000
IF(ISHAPS.LT.1) RETURN 038940 0000
BE =B(I,29) 038950 0000
STABNO=B(I,24) 038960 0000
IF(STABNO.GT.0.01) GO TO 1830 038970 0000
NSSEG =B(I,2) 038980 0000
MEX =B(I,7) 038990 0000
ELUATR=B(I,13) 039000 0000
D10 =B(I,16) 039010 0000
COHESN=B(I,17) 039020 0000
GAMMA =B(I,18) 039030 0000
PHI =B(I,19) 039040 0000
IWATER=B(I,21) 039050 0000

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COSTEN Listing (Continued)

	PERM =B(I,23)	039040 0000
	MSTAB =B(I,25)	039050 0000
	MUST =B(I,26)	039060 0000
	MSTAC =B(I,28)	039070 0000
	SEGDEP=B(I,36)	039080 0000
	NPTS =SHAFT(NSHAFT,2)	039090 0000
	ELSURF=CNP(NPTS,2)	039100 0000
	ELAUG =ELSURF-SEGDEP	039110 0000
	GO TO 1003	039120 0000
C	ROCK SHAFT	039130 0000
500	AIRPR=0	039140 0000
	B(I,27)=AIRPR	039150 0000
	MSTAB=0	039160 0000
	B(I,25)=MSTAB	039170 0000
	RETURN	039180 0000
C	-----	039190 0000
C	THIS IS A TUNNEL SEGMENT	039200 0000
1000	NTSTYP=A(I,16)	039210 0000
	IF(NTSTYP.EQ.1) GO TO 1002	039220 0000
	IF(NTSTYP.EQ.3) RETURN	039230 0000
	BE =A(I,39)	039240 0000
	STABNO=A(I,30)	039250 0000
	IF(STABNO.GT.0.01) GO TO 1830	039260 0000
	NTSEG =A(I,1)	039270 0000
	NPL =A(I,2)	039280 0000
	NPR =A(I,3)	039290 0000
	NREACH=A(I,4)	039300 0000
	NEX =A(I,7)	039310 0000
	ELWATR=A(I,14)	039320 0000
	NPLS =A(I,17)	039330 0000
	NPRS =A(I,18)	039340 0000
	D10 =A(I,19)	039350 0000
	PHI =A(I,20)	039360 0000
	COHESN=A(I,21)	039370 0000
	GAMMA =A(I,22)	039380 0000
	IWATER=A(I,23)	039390 0000
	ELIMP=A(I,24)	039400 0000
	PERM =A(I,25)	039410 0000
	MSTAB =A(I,31)	039420 0000
	MUST =A(I,32)	039430 0000
	MSTAC =A(I,34)	039440 0000
	ISHAPE=TRDATA(NREACH,3)	039450 0000
	ELNPL =CNP(NPL,2)	039460 0000
	ELNPR =CNP(NPR,2)	039470 0000
	ELNPLS=CNP(NPLS,2)	039480 0000
	ELNPRS=CNP(NPRS,2)	039490 0000
	ELSURF=(ELNPLS+ELNPRS)/2.	039500 0000
	ELAUG =(ELNPL+ELNPR)/2.	039510 0000
	SEGDEP=ELSURF-ELAUG	039520 0000
	GO TO 1003	039530 0000
C	ROCK TUNNEL	039540 0000
1002	AIRPR=0	039550 0000
	A(I,33)=AIRPR	039560 0000
	MSTAB=0	039570 0000
	A(I,31)=MSTAB	039580 0000
	RETURN	039590 0000
1003	AIRPR=0.	039600 0000
C	COMPUTE STABILITY NUMBER BASED ON INPUT PARAMETERS	039610 0000

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COSTUN Listing (Continued)

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MSTAB=0
CALL STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,
1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTAB,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE,
2 SEQDEP)
STABNO=STABNM
C CHECK WHETHER A PREFERRED STABILIZATION METHOD WAS INPUT. THE
C PREFERENCE COULD BE FOR USE OF NO METHOD AT ALL.
IF(MUST.GE.3) GO TO 1500
C NO METHOD IS PREFERRED BY USER. CHECK IF SEGMENT CAN BE EXCAVATED.
040100 0000
C THE PREFERRED METHOD IS DEWATERING
1010 MSTAB=2
MSTAB=2
CALL STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,
1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTAB,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE,
2 SEQDEP)
GO TO 1030
C THE PREFERRED METHOD IS COMPRESSED AIR
1015 CALL AIRPRS(AIRPR,D10,ELAUG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT,
1 STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)
MSTAB=1
1030 IF(ITYPE.EQ.1) A(I,30)=STABNM
IF(ITYPE.EQ.1) A(I,31)=MSTAB
IF(ITYPE.EQ.1) A(I,33)=AIRPR
IF(ITYPE.EQ.2) B(I,24)=STABNM
IF(ITYPE.EQ.2) B(I,25)=MSTAB
IF(ITYPE.EQ.2) B(I,27)=AIRPR
C CHECK WHETHER THE SEGMENT CAN BE EXCAVATED AFTER STABILIZATION
1035 IF(STABNM.LE.9. .AND.PHI.LT.29. .OR. STABNM.LE.7. .AND.PHI.GE.29.)
1 GO TO 1050
C SEGMENT CANNOT BE EXCAVATED EVEN AFTER USING A STABILIZATION METH.
IERROR=1
IF(ITYPE.EQ.1) WRITE(LO,2000)NTSEG,NREACH
IF(ITYPE.EQ.2) WRITE(LO,3000)NSSEG,NSHAFT
RETURN
C SEGMENT CAN NOW BE EXCAVATED. STORE THE NEW STABILITY NUMBER
1050 STABNO=STABNM
GO TO 1800
C -----
C SEGMENT CAN BE EXCAVATED WITHOUT BENEFIT OF STABILIZATION
C IF USER WILL ALLOW A STABILIZATION METHOD AND STABILITY NUMBER IS
C HIGH,CHECK WHETHER USE OF STABILIZATION WILL DECREASE STABILITY
C NUMBER BY AT LEAST 1.0
C -----
1200 IF(STABNO.LE.4.) GO TO 1300
IF(MUST.GT.1) GO TO 1300
C USER WILL ALLOW STABILIZATION TO BE USED
IF(D10.LE..005) GO TO 1215
AIRPR=0
IF(ELAUG.GE.ELWATR .OR.IWATR.EQ.0) GO TO 1205
IF(PERM.LT.0. .AND.ABS(PERM).GT.0.0006) GO TO 1209
IF(PERM.GT.0. .AND. D10.GT.0.08) GO TO 1209
C THE FIRST CHOICE METHOD IS GROUND INJECTIONS
1205 MSTAB=3
COHSGI=20000.*SQRT(10.*ABS(PERM))
STABNM=SIGMAT/(SHRSTR+COHSGI)
IF(STABNO-STABNM.GE.1.) GO TO 1235
C DECREASE IN STABILITY NUMBER CAUSED BY USE OF GROUND INJECTIONS IS

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COSTEN Listing (Continued)

C	SMALL. IF COMPRESSED AIR IS ACCEPTABLE,CHECK IF IT GIVES GREATER	040500	0000
C	DECREASE.	040600	0000
	IF(PERM.LT.0. .AND. ABS(PERM).GT.0.4) GO TO 1235	040610	0000
	IF(PERM.GT.0. .AND.D10.GT.2.) GO TO 1235	040620	0000
	IF(ELAUG.GE.ELWATR) GO TO 1207	040630	0000
	IF(ELWATR-ELAUG.GT.115.) GO TO 1235	040640	0000
C	COMPRESSED AIR IS AN ACCEPTABLE METHOD.	040650	0000
1207	CALL AIRPRS(AIRPR,D10,ELAUG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT,	040660	0000
	1 STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)	040670	0000
	MSTAB=1	040680	0000
	GO TO 1235	040690	0000
1209	IF(SEGDEP.LE.150.) GO TO 1210	040700	0000
C	GROUND WOULD BE DEWATERED EXCEPT THAT SEGMENT IS DEEPER THAN IS	040710	0000
C	USUALLY DESIRED. TRY GROUND INJECTIONS FIRST. IF STABILITY NUMBER	040720	0000
C	DOES NOT CHANGE BY MUCH,TRY DEWATERING INSTEAD.	040730	0000
	CONSGI=20000.*SQRT(10.*ABS(PERM))	040740	0000
	STABNM=SIGMAT/(SHRSTR+CONSGI)	040750	0000
	IF(STABNO-STABNM.GE.1.) GO TO 1235	040760	0000
C	THE PREFERRED METHOD IS DEWATERING	040770	0000
1210	MSTAB=2	040780	0000
	MSTAB=2	040790	0000
	CALL STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,	040800	0000
	1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMA,GAMHAB,GAMMAC,F,FSHAPE,	040810	0000
	2 SEGDEP)	040820	0000
	GO TO 1235	040830	0000
C	THE PREFERRED METHOD IS COMPRESSED AIR	040840	0000
1215	MSTAB=1	040850	0000
	CALL AIRPRS(AIRPR,D10,ELAUG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT,	040860	0000
	1 STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)	040870	0000
C	CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0	040880	0000
1235	IF(STABNO-STABNM.GE.1.) GO TO 1245	040890	0000
C	STABILITY NUMBER DECREASE IS LESS THAN 1.0 FORGET STABILIZATION	040900	0000
C	METHOD AND EXCAVATE USING ORIGINAL GROUND CONDITIONS	040910	0000
	MSTAB=0	040920	0000
	AIRPR=0.	040930	0000
	IF(ITYPE.EQ.1) GO TO 1240	040940	0000
	WRITE(LO,3010) NSSEG,NSHAFT	040950	0000
	B(I,24)=STABNO	040960	0000
	B(I,25)=MSTAB	040970	0000
	B(I,27)=AIRPR	040980	0000
	GO TO 1800	040990	0000
1240	WRITE(LO,2010) NTSEG,NREACH	041000	0000
	A(I,30)=STABNO	041010	0000
	A(I,31)=MSTAB	041020	0000
	A(I,33)=AIRPR	041030	0000
	GO TO 1800	041040	0000
C	STABILITY NUMBER DECREASED BY AT LEAST 1.0 USE STABILIZATION	041050	0000
C	METHOD AND NEW STABILITY NUMBER	041060	0000
1245	IF(MSTAB.GT.1) AIRPR=0.	041070	0000
	IF(ITYPE.EQ.1) GO TO 1250	041080	0000
	B(I,24)=STABNM	041090	0000
	B(I,25)=MSTAB	041100	0000
	B(I,27)=AIRPR	041110	0000
	STABNO=STABNM	041120	0000
	GO TO 1800	041130	0000
1250	A(I,30)=STABNM	041140	0000
	A(I,31)=MSTAB	041150	0000
	A(I,33)=AIRPR	041160	0000

(Continued)

COSTUN Listing (Continued)

	STABNO=STABNM	041170	0000
	GO TO 1800	041180	0000
1300	IF(ITYPE.EQ.1) A(I,30)=STABNO	041190	0000
	IF(ITYPE.EQ.2) B(I,24)=STABNO	041200	0000
	GO TO 1800	041210	0000
C	*****	041220	0000
C	A PREFERRED STABILIZATION METHOD WAS INPUT. THE PREFERENCE COULD	041230	0000
C	BE FOR USE OF NO METHOD AT ALL.	041240	0000
C	CAN THE SEGMENT BE EXCAVATED WITHOUT STABILIZATION	041250	0000
1500	IF(STABNO.LE.9. .AND.PHI.LT.29. .OR.STABNO.LE.7. .AND.PHI.GE.29.)	041260	0000
	1 GO TO 1600	041270	0000
C	-----	041280	0000
C	CHECK IF USER WILL ALLOW SOME METHOD TO BE USED.	041290	0000
	IF(MSTAB.GT.0) GO TO 1502	041300	0000
	IERROR=1	041310	0000
	IF(ITYPE.EQ.1) WRITE(LO,2050) NTSEG,NREACH	041320	0000
	IF(ITYPE.EQ.2) WRITE(LO,3050) NSSEG,NSHAFT	041330	0000
	GO TO 1530	041340	0000
C	-----	041350	0000
C	SEGMENT CANNOT BE EXCAVATED WITHOUT STABILIZATION. CHECK WHETHER	041360	0000
C	USERS PREFERRED METHOD IS ACCEPTABLE	041370	0000
1502	IF(ITYPE.EQ.2) GO TO 1505	041380	0000
	IF(MSTAC.EQ.1) GO TO 1510	041390	0000
C	METHOD IS UNACCEPTABLE	041400	0000
	IERROR=1	041410	0000
	WRITE(LO,3030) NSSEG,NSHAFT	041420	0000
	RETURN	041430	0000
1505	IF(MSTAC.EQ.1) GO TO 1510	041440	0000
C	METHOD IS UNACCEPTABLE	041450	0000
	IERROR=1	041460	0000
	WRITE(LO,2030) NTSEG,NREACH	041470	0000
	RETURN	041480	0000
C	-----	041490	0000
C	STABILIZATION METHOD INPUT IS ACCEPTABLE	041500	0000
C	CHECK FOR PREFERRED METHOD	041510	0000
1510	IF(MSTAB.EQ.1) GO TO 1520	041520	0000
	IF(MSTAB.EQ.3) GO TO 1518	041530	0000
C	THE PREFERRED METHOD IS DEWATERING	041540	0000
	MSTABT=2	041550	0000
	CALL STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE,	041560	0000
	1 PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE,	041570	0000
	2 SEGDEP)	041580	0000
	GO TO 1525	041590	0000
C	THE PREFERRED METHOD IS GROUND INJECTIONS	041600	0000
1518	CONSGI=20000.*SQRT(10.*ABS(PERM))	041610	0000
	STABNM=SIGMAT/(SHRSTR+CONSGI)	041620	0000
	GO TO 1525	041630	0000
C	THE PREFERRED METHOD IS COMPRESSED AIR	041640	0000
1520	IF(ITYPE.EQ.1) AIRPR=A(I,33)	041650	0000
	IF(ITYPE.EQ.2) AIRPR=B(I,27)	041660	0000
C	IF AIR PRESSURE IS INPUT,USE IT AND COMPUTE STABILITY NUMBER.IF	041670	0000
C	NONE IS INPUT,COMPUTE AIR PRESSURE	041680	0000
	IF(AIRPR.GT.0.) GO TO 1522	041690	0000
	CALL AIRPRS(AIRPR,D10,ELAUG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT,	041700	0000
	1STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)	041710	0000
	GO TO 1525	041720	0000
1522	STABNM=(SIGMAT-AIRPR*144.)/SHRSTR	041730	0000
C	CHECK WHETHER SEGMENT CAN BE EXCAVATED AFTER STABILIZATION	041740	0000

(Continued)

COSTUN Listing (Continued)

1525	IF(STABNM.LE.9. .AND.PHI.LT.29. .OR.STABNM.LE.7. .AND.PHI.GE.29.)	041753	0000
1	GO TO 1530	041760	0000
C	SEGMENT CANNOT BE EXCAVATED EVEN AFTER USING A STABILIZATION METH.	041770	0000
	ERROR=1	041780	0000
	IF(ITYPE.EQ.1) WRITE(LO,2035)NTSEG,NREACH	041790	0000
	IF(ITYPE.EQ.2) WRITE(LO,3035)NSSEG,NSHAFT	041800	0000
	IF(ITYPE.EQ.1) A(I,30)=STABNM	041810	0000
	IF(ITYPE.EQ.1) A(I,33)=AIRPR	041820	0000
	IF(ITYPE.EQ.2) B(I,24)=STABNM	041830	0000
	IF(ITYPE.EQ.2) B(I,27)=AIRPR	041840	0000
	GO TO 1830	041850	0000
C	-----	041860	0000
C	SEGMENT CAN NOW BE EXCAVATED	041870	0000
1530	IF(ITYPE.EQ.1) GO TO 1535	041880	0000
	B(I,24)=STABNM	041890	0000
	B(I,27)=AIRPR	041900	0000
	STABNO=STABNM	041910	0000
	GO TO 1800	041920	0000
1535	A(I,30)=STABNM	041930	0000
	A(I,33)=AIRPR	041940	0000
	STABNO=STABNM	041950	0000
	GO TO 1800	041960	0000
C	-----	041970	0000
C	SEGMENT CAN BE EXCAVATED WITHOUT BENEFIT OF STABILIZATION METHOD	041980	0000
C	-----	041990	0000
C	CHECK IF NO METHOD IS TO BE USED	042000	0000
1600	IF(MSTAB.EQ.0) GO TO 1640	042010	0000
C	CHECK WHETHER USER REQUIRES STABILIZATION METHOD TO BE USED	042020	0000
	IF(MUST.EQ.4) GO TO 1610	042030	0000
C	STABILIZATION IS NOT REQUIRED.FORGET STABILIZATION AND EXCAVATE	042040	0000
C	USING THE ORIGINAL GROUND CONDITIONS.	042050	0000
	IF(ITYPE.EQ.1) GO TO 1605	042060	0000
	WRITE(LO,3015) NSSEG,NSHAFT	042070	0000
	MSTAB=0	042080	0000
	B(I,24)=STABNO	042090	0000
	B(I,25)=MSTAB	042100	0000
	GO TO 1800	042110	0000
1605	WRITE(LO,2015) NTSEG,NREACH	042120	0000
	MSTAB=0	042130	0000
	A(I,30)=STABNO	042140	0000
	A(I,31)=MSTAB	042150	0000
	GO TO 1800	042160	0000
C	-----	042170	0000
C	USER REQUIRES USE OF A STABILIZATION METHOD. CHECK IF SPECIFIED	042180	0000
C	METHOD IS ACCEPTABLE. IF METHOD IS UNACCEPTABLE,BASE COSTS ON	042190	0000
C	UNSTABILIZED GROUND	042200	0000
1610	IF(ITYPE.EQ.1) GO TO 1615	042210	0000
	IF(MSTAB.EQ.1) GO TO 1620	042220	0000
	WRITE(LO,3020) NSSEG,NSHAFT	042230	0000
	GO TO 1800	042240	0000
1615	IF(MSTAB.EQ.1) GO TO 1620	042250	0000
	WRITE(LO,2020) NTSEG,NREACH	042260	0000
	GO TO 1800	042270	0000
C	-----	042280	0000
C	STABILIZATION METHOD INPUT IS ACCEPTABLE	042290	0000
C	CHECK FOR PREFERRED METHOD	042300	0000
1620	IF(MSTAB.EQ.1) GO TO 1630	042310	0000
	IF(MSTAB.EQ.3) GO TO 1625	042320	0000

(Continued)

COSTUN Listing (Continued)

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C   THE PREFERRED METHOD IS DEWATERING                                042330 0000
    NSTAB=2                                                            042340 0000
    CALL STABNU(COHESN,ELAVG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,ITYPE, 042350 0000
    1 PHI,SHRSTR,SIGMAT,STABNM,BE,NSTAB,GAMMAA,GAMMAB,GAMMAC,F,FSHAPE, 042360 0000
    2 SEQDEP)                                                            042370 0000
    GO TO 1635                                                            042380 0000
C   THE PREFERRED METHOD IS GROUND INJECTIONS                          042390 0000
1625 CONSGI=80000.XSORT(10,XABS(PERM))                                042400 0000
    STABNM=SIGMAT/(SHRSTR+CONSGI)                                       042410 0000
    GO TO 1635                                                            042420 0000
C   THE PREFERRED METHOD IS COMPRESSED AIR                             042430 0000
1630 IF(ITYPE.EQ.1) AIRPR=A(I,33)                                       042440 0000
    IF(ITYPE.EQ.2) AIRPR=B(I,27)                                       042450 0000
C   IF AIR PRESSURE IS INPUT,USE IT AND COMPUTE STABILITY NUMBER.IF 042460 0000
C   NONE IS INPUT,COMPUTE AIR PRESSURE                                042470 0000
    IF(AIRPR.GT.0.) GO TO 1632                                           042480 0000
    CALL AIRPRS(AIRPR,D10,ELAVG,ELWATR,IERROR,ITYPE,PHI,SHRSTR,SIGMAT, 042490 0000
    1 STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)                       042500 0000
    GO TO 1635                                                            042510 0000
1632 STABNM=(SIGMAT-AIRPR*144.)/SHRSTR                                   042520 0000
----- 042530 0000
C   CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0              042540 0000
1635 IF(STABNO-STABNM.GE.1.) GO TO 1640                                  042550 0000
C   STABILITY NUMBER DID NOT DECREASE BY AT LEAST 1.0 INFORM USER 042560 0000
    IF(ITYPE.EQ.1) WRITE(LO,2025) NTSEG,NREACH                          042570 0000
    IF(ITYPE.EQ.2) WRITE(LO,3025) NSSEG,NSHAFT                          042580 0000
1640 IF(ITYPE.EQ.1) A(I,30)=STABNM                                       042590 0000
    IF(ITYPE.EQ.1) A(I,33)=AIRPR                                         042600 0000
    IF(ITYPE.EQ.2) B(I,24)=STABNM                                       042610 0000
    IF(ITYPE.EQ.2) B(I,27)=AIRPR                                         042620 0000
    STABNO=STABNM                                                         042630 0000
C   *****                                                            042640 0000
C   CHECK FOR ACCEPTABLE EXCAVATION METHOD FOR THE STABILITY NUMBER 042650 0000
C   TO BE USED,THE CHECK FOR COMPATIBILITY WITH SHAPE IS IN SUB INPUT 042660 0000
1800 IF(ITYPE.EQ.1)GO TO 1805                                           042670 0000
    IF(MEX.EQ.4) GO TO 1830                                              042680 0000
    IF(MEX.EQ.3 .AND. STABNO.LE.6.) GO TO 1830                         042690 0000
C   METHOD IS UNACCEPTABLE,SELECT HAND METHODS INSTEAD              042700 0000
    MEX=4                                                                042710 0000
    B(I,7)=MEX                                                           042720 0000
    WRITE(LO,3040) NSSEG,NSHAFT                                          042730 0000
    GO TO 1830                                                            042740 0000
1805 IF(MEX=4) 1820,1830,1810                                           042750 0000
C   RIPPER EXCAVATION                                                042760 0000
1810 IF(STABNO.LE.7.) GO TO 1830                                         042770 0000
    GO TO 1825                                                            042780 0000
C   MOLE EXCAVATION                                                  042790 0000
1820 IF(STABNO.LE.6.) GO TO 1830                                         042800 0000
C   MOLE OR RIPPER ARE UNACCEPTABLE,SELECT HAND INSTEAD            042810 0000
1825 MEX=4                                                              042820 0000
    A(I,7)=MEX                                                           042830 0000
    WRITE(LO,2040) NTSEG,NREACH                                          042840 0000
C   *****                                                            042850 0000
C   IF STABILITY NUMBER IS LOW,SHIELD IS VERY THIN AND LEAVES LITTLE 042860 0000
C   SPACE FOR BACKFILL BEHIND THE LINING OR SUPPORT                 042870 0000
1830 BOB=BE+1.0                                                         042880 0000
    IF(STABNO.LT.2.) BOB=BE                                              042890 0000
    IF(ITYPE.EQ.1) A(I,48)=BOB                                          042900 0000

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(Continued)

COSTUN Listing (Continued)

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      IF(ITYPE.EQ.2) B(I,32)=303
      RETURN
C *****
2000 FORMAT(/, ' FATAL ERROR, STABILITY NUMBER IN SEGMENT', I5, ' IN RE
1ACH', I5, ' IS TOO HIGH TO ALLOW EXCAVATION, EVEN AFTER STABILIZATIO
2N')
2010 FORMAT(/, ' **** REMINDER **** USE OF A STABILIZATION METHOD IN
1SEGMENT', I5, ' IN REACH', I5, ' IS NOT VERY EFFECTIVE, NO METHOD USE
2D')
2015 FORMAT(/, ' **** REMINDER **** USER PREFERRED STABILIZATION METH
1OD IN SEGMENT', I5, ' IN REACH', I5, ' IS NOT REQUIRED, METHOD NOT US
2ED')
2020 FORMAT(/, ' **** WARNING **** USERS STAB. METHOD IN SEGMENT', I5,
1' IN REACH', I5, ' IS NOT ACCEPTABLE NOR REQUIRED, METHOD NOT USE
2D')
2025 FORMAT(/, ' **** REMINDER **** USE OF STABILIZATION METHOD IN SEG
1MENT', I5, ' IN REACH', I5, ' IS NOT VERY EFFECTIVE, METHOD USED ANYW
2AY')
2030 FORMAT(/, ' FATAL ERROR, USERS STAB. METHOD IN SEGMENT', I5, ' IN R
2EACH', I5, ' IS NOT ACCEPTABLE AND STABILITY NUMBER IS TOO HIGH')
2035 FORMAT(/, ' FATAL ERROR, USERS STAB. METHOD IN SEGMENT', I5, ' IN R
1EACH', I5, ' IS NOT EFFECTIVE AND STABILITY NUMBER IS TOO HIGH')
2040 FORMAT(/, ' **** REMINDER **** CONDITIONS IN SEGMENT', I5, ' IN REA
1CH', I5, ' REQUIRE USE OF HAND EXCAVATION RATHER THAN INPUT METHOD')
2050 FORMAT(/, ' FATAL ERROR, STABILITY NUMBER IN SEGMENT', I5, ' IN REA
1CH', I5, ' REQUIRES GROUND STABILIZATION, BUT IT WAS SPECIFIED NO M
2ETHOD BE USED')
3000 FORMAT(/, ' FATAL ERROR, STABILITY NUMBER IN SEGMENT', I5, ' IN SH
1AFT', I5, ' IS TOO HIGH TO ALLOW EXCAVATION, EVEN AFTER STABILIZATIO
2N')
3010 FORMAT(/, ' **** REMINDER **** USE OF A STABILIZATION METHOD IN
1SEGMENT', I5, ' IN SHAFT', I5, ' IS NOT VERY EFFECTIVE, NO METHOD USE
2D')
3015 FORMAT(/, ' **** REMINDER **** USER PREFERRED STABILIZATION METH
1OD IN SEGMENT', I5, ' IN SHAFT', I5, ' IS NOT REQUIRED, METHOD NOT US
2ED')
3020 FORMAT(/, ' **** WARNING **** USERS STAB. METHOD IN SEGMENT', I5,
1' IN SHAFT', I5, ' IS NOT ACCEPTABLE NOR REQUIRED, METHOD NOT USE
2D')
3025 FORMAT(/, ' **** REMINDER **** USE OF STABILIZATION METHOD IN SEG
1MENT', I5, ' IN SHAFT', I5, ' IS NOT VERY EFFECTIVE, METHOD USED ANYW
2AY')
3030 FORMAT(/, ' FATAL ERROR, USERS STAB. METHOD IN SEGMENT', I5, ' IN S
1HAFT', I5, ' IS NOT ACCEPTABLE AND STABILITY NUMBER IS TOO HIGH')
3035 FORMAT(/, ' FATAL ERROR, USERS STAB. METHOD IN SEGMENT', I5, ' IN S
1HAFT', I5, ' IS NOT EFFECTIVE AND STABILITY NUMBER IS TOO HIGH')
3040 FORMAT(/, ' **** REMINDER **** CONDITIONS IN SEGMENT', I5, ' IN SHA
1FT', I5, ' REQUIRE USE OF HAND EXCAVATION RATHER THAN INPUT METHOD')
3050 FORMAT(/, ' FATAL ERROR, STABILITY NUMBER IN SEGMENT', I5, ' IN SHA
1FT', I5, ' REQUIRES GROUND STABILIZATION, BUT IT WAS SPECIFIED NO M
2ETHOD BE USED')
-----
      RETURN

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042913 0000
042923 0000
042933 0000
042940 0000
042950 0000
042960 0000
042970 0000
042980 0000
042990 0000
043000 0000
043010 0000
043020 0000
043030 0000
043040 0000
043050 0000
043060 0000
043070 0000
043080 0000
043090 0000
043100 0000
043110 0000
043120 0000
043130 0000
043140 0000
043150 0000
043160 0000
043170 0000
043180 0000
043190 0000
043200 0000
043210 0000
043220 0000
043230 0000
043240 0000
043250 0000
043260 0000
043270 0000
043280 0000
043290 0000
043300 0000
043310 0000
043320 0000
043330 0000
043340 0000
043350 0000
043360 0000
043370 0000
043380 0000
043390 0000
043400 0000
043410 0000
043420 0000
043430 0000
043440 0000
043450 0000
043455

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COSTUN Listing (Continued)

	END	043460	0000
	SUBROUTINE STABNU(COHESN,ELAUG,ELSURF,ELWATR,GAMMA,ISHAPE,ISHAPS,	043470	0000
	1 ITYPE,PHI,SHRSTR,SIGMAT,STABNM,BE,MSTABT,GAMMAA,GAMMAB,GAMMAC,F,	043480	0000
	2 FSHAPE,SEGDEP)	043490	0000
C	-----	043500	0000
C	THIS SUBROUTINE COMPUTES THE INITIAL STABILITY NUMBER BASED ONLY	043510	0000
C	ON INPUT GROUND PARAMETERS AND ALSO COMPUTES IT IF STABILIZATION	043520	0000
C	IS BY DEWATERING	043530	0000
C	-----	043540	0000
C	-----	043550	0000
C	PI=3.14159	043560	0000
	SINPHI=SIN(PHI*PI/180.)	043570	0000
	TANPHI=TAN(PHI*PI/180.)	043580	0000
C	CHECK WHETHER THIS IS THE SECOND COMPUTATION FOR THIS SEGMENT. IF	043590	0000
C	SO,CAN BYPASS MOST OF THIS SUBROUTINE.	043600	0000
	IF(MSTABT.EQ.2) GO TO 1150	043610	0000
C	COMPUTE STABILITY NUMBER FOR UNSTABILIZED GROUND	043620	0000
C	CHECK FOR GWT ABOVE GROUND SURFACE	043630	0000
C	IF(ELWATR.GT.ELSURF) GO TO 1050	043640	0000
C	CHECK FOR SEGMENT BELOW GWT	043650	0000
	IF(ELAUG.LT.ELWATR) GO TO 1010	043660	0000
C	GWT IS BELOW SEGMENT	043670	0000
	SIGGAH=SEGDEP*XGAMMA	043680	0000
	IF(SEGDEP.LE.2.*BE) GO TO 1000	043690	0000
	GAMMAA=GAMMA	043700	0000
	GAMMAB=GAMMA	043710	0000
	GO TO 1100	043720	0000
1000	GAMMAC=GAMMA	043730	0000
	GO TO 1100	043740	0000
C	SEGMENT IS BELOW GWT	043750	0000
1010	DUATER=ELSURF-ELWATR	043760	0000
	SIGGAH=DUATER*XGAMMA+(ELWATR-ELAUG)*(GAMMA-62.4)	043770	0000
	IF(SEGDEP.LE.2.*BE) GO TO 1030	043780	0000
	IF(DUATER.GT.2.*BE) GO TO 1020	043790	0000
C	SEGMENT IS DEEPER THAN 2BE AND GWT IS WITHIN 2BE OF GROUND SURFACE	043800	0000
	GAMMAA=(GAMMA*DUATER+(GAMMA-62.4)*(2.*BE-DUATER))/(2.*BE)	043810	0000
	GAMMAB=(GAMMA-62.4)	043820	0000
	GO TO 1100	043830	0000
C	SEGMENT AND GWT ARE BOTH DEEPER THAN 2BE	043840	0000
1020	GAMMAA=GAMMA	043850	0000
	GAMMAB=(GAMMA*(DUATER-2.*BE)+(GAMMA-62.4)*(ELWATR-ELAUG))/(SEGDEP-	043860	0000
	1 2.*BE)	043870	0000
	GO TO 1100	043880	0000
C	SEGMENT IS WITHIN 2BE OF GROUND SURFACE	043890	0000
1030	GAMMAC=(GAMMA*DUATER+(GAMMA-62.4)*(ELWATR-ELAUG))/SEGDEP	043900	0000
	GO TO 1100	043910	0000
C	GWT IS ABOVE GROUND SURFACE	043920	0000
1050	GAMMAA=GAMMA-62.4	043930	0000
	GAMMAB=GAMMA-62.4	043940	0000
	GAMMAC=GAMMA-62.4	043950	0000
	SIGGAH=SEGDEP*(GAMMA-62.4)	043960	0000
		043970	0000

(Continued)

COSTUM Listing (Continued)

C	-----	043980	0000
1100	PHIEQR=ATAN(COHESN/SIGGAH+TANPHI)	043990	0000
	PHIEQ=PHIEQR*180./PI	044000	0000
	IF(PHIEQ.GT.45.) PHIEQ=45.	044010	0000
C	ESTABLISH SEGMENT TYPE AND SHAPE FACTORS	044020	0000
	IF(SEGDEP.LE.2.*BE) GO TO 1300	044030	0000
	F=1.0	044040	0000
	FSHAPE=1.0	044050	0000
	IF(ITYPE.EQ.1) GO TO 1110	044060	0000
C	SHAFT SEGMENT	044070	0000
	F=0.5	044080	0000
	FSHAPE=0.5	044090	0000
	IF(ISHAPS.EQ.2) F=0.6	044100	0000
	IF(ISHAPS.EQ.2) FSHAPE=0.6	044110	0000
	GO TO 1200	044120	0000
C	TUNNEL SEGMENT	044130	0000
1110	IF(ISHAPE.EQ.3) FSHAPE=1.25	044140	0000
	GO TO 1200	044150	0000
C	-----	044160	0000
	THE FOLLOWING UNIT WEIGHTS ARE FOR STABILIZATION BY DEWATERING	044170	0000
1150	IF(SEGDEP.LE.2.*BE) GO TO 1160	044180	0000
	GAMMA=GAMMA	044190	0000
	GAMMA=GAMMA	044200	0000
	GO TO 1200	044210	0000
1160	GAMMA=GAMMA	044220	0000
	GO TO 1350	044230	0000
C	-----	044240	0000
	SEGMENT IS DEEPER THAN 2BE	044250	0000
1200	SIGMAT=2.*BE*GAMMA*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)*	044260	0000
	1 GAMMA*FSHAPE	044270	0000
C	INCREASE SIGMAT IF GUT IS ABOVE GROUND AND SEGMENT NOT DEWATERED	044280	0000
	IF(MSTABT.EQ.2) GO TO 1250	044290	0000
	IF(ELUATR.GT.ELSUF) SIGMAT=SIGMAT+(ELUATR-ELSUF)*62.4	044300	0000
1250	SIGMA1=2.*BE*GAMMA*F+(SEGDEP-2.*BE)*(0.34-PHIEQ**2./6000.)*	044310	0000
	1 GAMMA*FSHAPE	044320	0000
	GO TO 1400	044330	0000
C	SEGMENT IS NO DEEPER THAN 2BE	044340	0000
1300	F=1.0	044350	0000
	IF(ITYPE.EQ.1) GO TO 1350	044360	0000
C	SHAFT SEGMENT	044370	0000
	F=0.5	044380	0000
	IF(ISHAPS.EQ.2) F=0.6	044390	0000
1350	SIGMAT=SEGDEP*GAMMA*F	044400	0000
C	INCREASE SIGMAT IF GUT IS ABOVE GROUND AND SEGMENT NOT DEWATERED	044410	0000
	IF(MSTABT.EQ.2) GO TO 1375	044420	0000
	IF(ELUATR.GT.ELSUF) SIGMAT=SIGMAT+(ELUATR-ELSUF)*62.4	044430	0000
1375	SIGMA1=SEGDEP*GAMMA*F	044440	0000
C	-----	044450	0000

(Continued)

COSTUM Listing (Continued)

C	COMPUTE STABILITY NUMBER	044460	0000
1400	FRSTRN=SIGMA1/2.*(1.-SINPHI)*TANPHI	044470	0000
	SHRSTR=COHESN+FRSTRN	044480	0000
	STABNM=SIGMAT/SHRSTR	044490	0000
C	-----	044500	0000
	RETURN	044510	0000
	END	044520	0000
	SUBROUTINE AIRPRS(AIRPR ,D10,ELAUG,ELWATR,IEROR,ITYPE,PHI,SHRSTR,	044530	0000
	1SIGMAT,STABNM,STABNO,LO,NREACH,NSHAFT,NSSEG,NTSEG)	044540	0000
C	-----	044550	0000
C	-----	044560	0000
C	THIS SUBROUTINE DETERMINES THE AIR PRESSURE TO BE USED FOR SOFT	044570	0000
C	GROUND CONSTRUCTION IN COMPRESSED AIR	044580	0000
C	-----	044590	0000
C	-----	044600	0000
C	-----	044610	0000
C	-----	044620	0000
C	CHECK FOR GRANULAR MATERIAL BELOW GWT. IF SO, AIR PRESSURE IS	044630	0000
C	CONTROLLED BY WATER HEAD	044640	0000
C	IF(D10.GT. .005 .AND.ELAUG.LT.ELWATR) AIRPR=.433*(ELWATR-ELAUG)	044650	0000
C	IF(D10.GT. .005 .AND.ELAUG.LT.ELWATR) RETURN	044660	0000
C	-----	044670	0000
C	AIR PRESSURE IS NOT CONTROLLED BY WATER HEAD. START BY COMPUTING	044680	0000
C	STABILITY NUMBER USING MINIMUM AIR PRESSURE OF 7 PSI.	044690	0000
C	AIRPR=7.0	044700	0000
C	STABNM=(SIGMAT-AIRPR*144.)/SHRSTR	044710	0000
C	CHECK FOR STABILITY NUMBER DECREASE OF AT LEAST 1.0	044720	0000
C	IF(STABNO-STABNM.GE.1.) GO TO 1100	044730	0000
C	DECREASE LESS THAN 1.0 COMPUTE AIR PRESURE FOR DECREASE= 1.0	044740	0000
C	AIRPR=(SIGMAT-(STABNO-1.)*SHRSTR)/144.	044750	0000
C	CHECK FOR AIR PRESSURE GREATER THAN 50 PSI	044760	0000
C	IF(AIRPR.GT.50.) GO TO 1000	044770	0000
C	AIR PRESSURE IS LESS THAN 50 PSI. CAN SEGMENT BE EXCAVATED	044780	0000
C	IF(STABNO-1. .LE.9. .AND.PHI.LT.29. .OR.STABNO-1. .LE.7. .AND.PHI	044790	0000
C	1 .GE.29.) GO TO 1050	044800	0000
C	SEGMENT CANNOT BE EXCAVATED FOR STABILITY NUMBER DECREASE OF 1.0	044810	0000
C	CAUSED BY APPLICATION OF AIR PRESSURE,OR DECREASE OF 1.0 REQUIRES	044820	0000
C	AIR PRESSURE GREATER THAN 50 PSI. TRY 50 PSI	044830	0000
1000	AIRPR=50.	044840	0000
	STABNM=(SIGMAT-AIRPR*144.)/SHRSTR	044850	0000

(Continued)

COSTUN Listing (Continued)

C	CHECK WHETHER SEGMENT CAN BE EXCAVATED USING 50 PSI	044860	0000
	IF(STABNM.LE.9. .AND. PHI.LT.29. .OR.STABNM.LE.7. .AND.PHI.GE.29.)	044870	0000
1	GO TO 1200	044880	0000
C	SEGMENT CANNOT BE EXCAVATED USING 50 PSI,MAXIMUM ALLOWABLE PRESS.	044890	0000
	IERROR=1	044900	0000
	IF(ITYPE.EQ.1) WRITE(LO,2000) NTSEG,NREACH	044910	0000
	IF(ITYPE.EQ.2) WRITE(LO,3000) NSSEG,NSHAFT	044920	0000
	GO TO 1200	044930	0000
C	SEGMENT CAN BE EXC USING AIR PRESSURE FOR STABNO DECREASE=1.0	044940	0000
1050	STABNM=STABNO-1.	044950	0000
	GO TO 1200	044960	0000
C	-----	044970	0000
C	STABILITY NUMBER DECREASE BY AT LEAST 1.0 FOR 7 PSI AIR PRESSURE.	044980	0000
C	CAN SEGMENT BE EXCAVATED	044990	0000
1100	IF(STABNM.LE.9. .AND.PHI.LT.29. .OR.STABNM.LE.7. .AND.PHI.GE.29.)	045000	0000
1	GO TO 1200	045010	0000
C	SEGMENT CANNOT BE EXCAVATED FOR DECREASE=1.0 USING 7 PSI. COMPUTE	045020	0000
C	AIR PRESSURE SO SEGMENT CAN BE EXCAVATED	045030	0000
	SN=9.	045040	0000
	IF(PHI.GE.29.) SN=7.	045050	0000
	AIRPR=(SIGMAT-SNXSHRSTR)/144.	045060	0000
C	CHECK FOR AIR PRESSURE GREATER THAN 50 PSI	045070	0000
	IF(AIRPR.GT.50.) GO TO 1150	045080	0000
C	AIR PRESSURE LESS THAN 50 PSI	045090	0000
	STABNM=SN	045100	0000
	GO TO 1200	045110	0000
C	SEGMENT CANNOT BE EXCAVATED USING 50 PSI,MAXIMUM ALLOWABLE PRESS.	045120	0000
1150	IERROR=1	045130	0000
	IF(ITYPE.EQ.1) WRITE(LO,2000) NTSEG,NREACH	045140	0000
	IF(ITYPE.EQ.2) WRITE(LO,3000) NSSEG,NSHAFT	045150	0000
1200	RETURN	045160	0000
C	-----	045170	0000
2000	FORMAT(/, ' FATAL ERROR, SEGMENT',I5, ' IN REACH',I5, ' CANNOT BE	045180	0000
	EXCAVATED USING LESS THAN 50 PSI AIR PRESSURE FOR STABILIZATION')	045190	0000
3000	FORMAT(/, ' FATAL ERROR, SEGMENT',I5, ' IN SHAFT',I5, ' CANNOT BE	045200	0000
	EXCAVATED USING LESS THAN 50 PSI AIR PRESSURE FOR STABILIZATION')	045210	0000
C	-----	045220	0000
	RETURN	045225	
	END	045230	0000

(Continued)

COSTUN Listing (Continued)

	SUBROUTINE REACHD(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX, INTRMAX)	045240 0000
	-----	045245
	THIS SUBROUTINE DETERMINES THE BEGINNING SEGMENT AND TOTAL NUMBER OF SEGMENTS IN THE REACHES.	045250 0000
	-----	045255 0000
	N1 LOCATION IN (A) ARRAY OF LEFT SEGMENT IN A REACH	045260 0000
	N2 LOCATION IN (A) ARRAY OF RIGHT SEGMENT IN A REACH	045270 0000
	I TUNNEL SEGMENT SEQUENCE NUMBER	045280 0000
	-----	045290 0000
	COMMON /BASIC/ NSS,NTS	045300 0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23), 1 TRDATA(INTRMAX,23)	045310 0000
	-----	045320 0000
	N1=1	045330 0000
	I=0	045340 0000
	IPR=A(1,4)	045350 0000
	NREACH=IPR	045360 0000
	NPL=A(1,2)	045370 0000
	NPR=A(1,3)	045380 0000
	STANPL=CNP(NPL,1)	045390 0000
	STANPR=CNP(NPR,1)	045400 0000
	STANLS=(STANPL+STANPR)/2.	045410 0000
	NSHAFT=TRDATA(NREACH,1)	045420 0000
	NPBS=SHAFT(NSHAFT,3)	045430 0000
	STANPB=CNP(NPBS,1)	045440 0000
	-----	045450 0000
C	100 I=I+1	045460 0000
	NREACH=A(I,4)	045470 0000
	IF(I.EQ.NTS+1) GO TO 200	045480 0000
	IF(NREACH.NE.IPR) GO TO 200	045490 0000
	N2=I	045500 0000
	GO TO 500	045510 0000
	-----	045520 0000
C	200 IF(STANLS.LT.STANPB) GO TO 250	045530 0000
	NRSEG1=N1	045540 0000
	NSEGS=N2-N1+1	045550 0000
	GO TO 300	045560 0000
	250 NRSEG1=N2	045570 0000
	NSEGS=-(N2-N1+1)	045580 0000
	300 TRDATA(IPR,5)=NRSEG1	045590 0000
	TRDATA(IPR,6)=NSEGS	045600 0000
	IF(I.EQ.NTS+1) GO TO 600	045610 0000
	-----	045620 0000
C	NPL=A(I,2)	045630 0000
	NPR=A(I,3)	045640 0000
	STANPL=CNP(NPL,1)	045650 0000
	STANPR=CNP(NPR,1)	045660 0000
	STANLS=(STANPL+STANPR)/2.	045670 0000
	NSHAFT=TRDATA(NREACH,1)	045680 0000
	NPBS=SHAFT(NSHAFT,3)	045690 0000
	STANPB=CNP(NPBS,1)	045700 0000
	IPR=NREACH	045710 0000
		045720 0000
		045730 0000
		045740 0000
		045750 0000
		045760 0000
		045770 0000

(Continued)

COSTUN Listing (continued)

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N1=1
N2=1
C 500 IF(I.NE.NTS+1) GO TO 100
C 600 CONTINUE
-----
C RETURN
C END
C SUBROUTINE ADRATE (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
C NTRMAX)
-----
C-----
C-----
C THIS SUBROUTINE COMPUTES THE ULTIMATE HEADING ADVANCE RATE FOR
C SEGMENTS IN WHICH NONE WAS USER SPECIFIED AND COMPUTES THE AVERAGE
C ADVANCE RATE IN ALL SEGMENTS
C-----
C-----
C COMMON /BASIC/ NSS,NTS
C DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
C 1 TRDATA(NTRMAX,23)
C-----
C-----
C COMPUTE ADVANCE RATES IN TUNNEL SEGMENTS
C DO 400 NREACH=1,NTRMAX
C IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 400
C NRSEG1=TRDATA(NREACH,5)
C NSEGS=TRDATA(NREACH,6)
C NSEGS=IABS(NSEGS)
C INITIALIZE VALUES
C PINSR=0.
C MEXP=0
C DO 300 I=1,NSEGS
C N=SEQUENCE NUMBER OF TUNNEL SEGMENT
C IF(NSEGS.GT.0) N=NRSEG1+I-1
C IF(NSEGS.LT.0) N=NRSEG1-I+1
C MEX=A(N,7)
C STABNO=A(N,30)
C E=2.71828
C AR=A(N,8)
C TSEGL=A(N,45)
C IF(MEX.GT.5) GO TO 1000
C CHECK FOR EXCAVATION IN DOWNHILL DIRECTION
C IF EXCAVATION IS DOWNHILL,ULTIMATE ADVANCE RATE IS ONLY 90 PERCENT
C OF ULTIMATE RATE FOR LEVEL OR UPHILL EXCAVATION
C SLARF=1.0
C NPL=A(N,2)
C NPR=A(N,3)
C ELNPL=CNP(NPL,2)
C ELNPR=CNP(NPR,2)
C SLOPE=(ELNPL-ELNPR)/(CNP(NPL,1)-CNP(NPR,1))
C IF(NSEGS.GT.0 .AND. SLOPE.LT.0 .OR. NSEGS.LT.0 .AND. SLOPE.GT.0.)
C 1 SLARF=0.9
C SE=A(N,39)
C RS=A(N,6)
C RQD=A(N,6)
C GI=A(N,9)

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(Continued)

COSEEN Listing (Continued)

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MSTAB=A(N,31)
GO TO 30
1000 ISUPPT=A(N,26)
GO TO 10
30 IF(MEX.EQ.MEXP) GO TO 10
C THIS IS FIRST SEGMENT IN REACH OR EXCAVATION METHOD HAS CHANGED
BINSAR=0.
GO TO 20
C EXCAVATION IS SAME AS IN PREVIOUS SEGMENT
10 BINSAR=PINSAR-.05
IF(BINSAR.LT.0.) BINSAR=0.
20 IF(AR.GT.0.) ARTULT=AR
IF(AR.GT.0.) GO TO 100
C -----
C AN ULTIMATE ADVANCE RATE HAS NOT BEEN SPECIFIED,MUST COMPUTE ONE
C COMPUTE SYSTEM ADVANCE RATES IN FEET/24 HOURS
C CHECK FOR METHOD OF EXCAVATION
1020 IF(MEX.GT.5) GO TO 1100
C THIS IS NOT CUT AND COVER
ISHAPE=TRDATA(NREACH,3)
IF(MEX.NE.2.AND.MEX.NE.3) GO TO 50
IF(MEX.EQ.2) GO TO 150
C -----
C MOLE IN SOFT GROUND
ARTULT=(2.X(STABNO-7.)**2 +1.)/100000.X(80.-BE)**3.XSLARF
GO TO 1100
C MOLE IN ROCK
ADVANCE RATE EQUATION NOT GOOD FOR ROCK STRENGTH BELOW 3000 PSI
150 IF(RS.LT.3000.) RS=3000.
ARTULT=(10000000./((BE*RS)**(.6+.4*SIN(3.14159*(ROD/75.+1.167))))
1X(GI+1500.)/(5.XGI+1500.)XSLARF
GO TO 1100
C -----
C CONVENTIONAL EXCAVATION IN ROCK OR HAND OR RIPPER EXC IN SOFT GRND
50 IF(ISHAPE.EQ.1) SFA=0.785
IF(ISHAPE.EQ.2) SFA=0.893
IF(ISHAPE.EQ.3) SFA=0.425
IF(MEX.EQ.1) ARTULT=((0.08*BE**2.25)*ROD+1000.)*((GI+1500.)/
1 (5.XGI+1500.)))/(SFA*BE**1.5*EXX(.035*BE)*(1.+.0025*RS/1000.))*
2 SLARFX(1.-ROD*(BE-10.)/6000.)
IF(MEX.EQ.1) GO TO 1200
IF(MEX.EQ.4) ARTULT=(0.3*(STABNO-10.))**2 +1.)/100000.X
1 (80.-BE)**3.XSLARFX0.785/SFA
IF(MEX.EQ.5) ARTULT=(1.4*(STABNO-7.5))**2 +1.)/100000.X
1 (80.-BE)**3.XSLARFX0.785/SFA
IF(ISHAPE.NE.3) GO TO 1100
C -----
C SHAPE IS BASKETHANDLE. CHECK FOR COMPUTED ADVANCE RATE GREATER
C THAN FOR CIRCLE OF SAME BE FOR STABILITY NUMBER = 0. IF GREATER,
C SET ARTULT FOR BASKETHANDLE EQUAL TO MAXIMUM RATE FOR CIRCLE.
IF(MEX.EQ.4) ART=0.00031X(80.-BE)**3.XSLARF
IF(MEX.EQ.5) ART=0.0007975X(80.-BE)**3.XSLARF
IF(ARTULT.GT.ART) ARTULT=ART
C -----
C CHECK FOR SOFT GROUND FACE STABILIZATION BY GROUND INJECTIONS
1100 IF(MSTAB.NE.3) GO TO 1200
C GROUND INJECTIONS ARE USED.CHECK FOR APPLICATION FROM INSIDE SEG.
NPLS=A(N,17)

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COSTEN Listing (Continued)

NPRS=A(N,18)	046930 0000
ELNPLS=CNP(NPLS,2)	046940 0000
ELNPRS=CNP(NPRS,2)	046950 0000
ELSURF=(ELNPLS+ELNPRS)/2.	046960 0000
ELAUG=(ELNPL+ELNPR)/2.	046970 0000
SEGDEP=ELSURF-ELAUG	046980 0000
IF(ISHAPE.NE.3) GO TO 1120	046990 0000
IF(SEGDEP-BE/4. .GT.50.) GO TO 1150	047000 0000
GO TO 1200	047010 0000
1120 IF(SEGDEP-BE/2. .GT.50.) GO TO 1150	047020 0000
GO TO 1200	047030 0000
C GROUND INJECTIONS ARE MADE FROM WITHIN SEGMENT AND SLOWS ADVANCE	047040 0000
1150 ARTULT=100./(100.+ARTULT)*ARTULT	047050 0000
GO TO 1200	047060 0000
C -----	047070 0000
C CUT AND COVER	047080 0000
1160 SIDESL=A(N,53)	047090 0000
IF(SIDESL.GT.0.) GO TO 1180	047100 0000
C VERTICAL CUT	047110 0000
IF(ISUPPT.EQ.5) ARTULT=15.+7.*ATAN(3.-STABNO)	047120 0000
IF(ISUPPT.EQ.6) ARTULT=18.+5.*ATAN(4.-STABNO)	047130 0000
GO TO 1200	047140 0000
C SLOPING CUT	047150 0000
1180 DTRNCH=A(N,52)	047160 0000
ARTULT=15000./((SIDESL*(20.+DTRNCH)+300.))	047170 0000
C CONVERT COMPUTED ADVANCE RATES TO FEET/HOURS WORKED. INPUT RATES	047180 0000
C ARE ALREADY IN FEET/HOURS WORKED	047190 0000
1200 HOURS=TRDATA(NREACH,8)	047200 0000
SHIFTS=1	047210 0000
IF(HOURS.GE.12.) SHIFTS=2.	047220 0000
IF(HOURS.GE.21.) SHIFTS=3.	047230 0000
EFFAC=1.	047240 0000
IF(HOURS/SHIFTS.GT.8.) EFFAC=1.0-0.01*(HOURS/SHIFTS-8.)*2.	047250 0000
ARTULT=ARTULT*EFFAC*HOURS/24.	047260 0000
C -----	047270 0000
100 IF(TSEGL.LE.25.*(1.-BINSAR**2.)*ARTULT) GO TO 120	047280 0000
C ULTIMATE ADVANCE RATE IS ATTAINED	047290 0000
ARFAC=TSEGL/(25.*(1.-BINSAR)**2 *ARTULT+TSEGL)	047300 0000
PINSAR=1.0	047310 0000
GO TO 240	047320 0000
C ULTIMATE ADVANCE RATE NEVER ATTAINED, SEGMENT TOO SHORT	047330 0000
120 ARFAC=.5*(BINSAR+SQRT(BINSAR**2.+0.04*TSEGL/ARTULT))	047340 0000
PINSAR=SQRT(BINSAR**2.+0.04*TSEGL/ARTULT)	047350 0000
240 MEXP=MEX	047360 0000
C COMPUTE AND STORE AVERAGE ADVANCE RATE FOR EACH SEGMENT	047370 0000
A(N,49)=ARTULT	047380 0000
300 A(N,8)=ARTULT*ARFAC	047390 0000
400 CONTINUE	047400 0000
C -----	047410 0000
C	047420 0000
C COMPUTE ADVANCE RATES IN SHAFT SEGMENTS	047430 0000
DO 800 NSHAFT=1,NSMAX	047440 0000
IF(SHAFT(NSHAFT,1).LE.-10.E29) GO TO 800	047450 0000
C IF THE SHAFT IS A PORTAL, SKIP ADVANCE RATE COMPUTATIONS	047460 0000
NPORT=SHAFT(NSHAFT,23)	047470 0000
IF(NPORT.EQ.1) GO TO 800	047480 0000
NSSEG1=SHAFT(NSHAFT,1)	047490 0000
NSEGS=SHAFT(NSHAFT,4)	047500 0000

(Continued)

COSTUN Listing (Continued)

C	INITIALIZE VALUES	047510	0000
	PINSAR=0.	047520	0000
	MEXP=0	047530	0000
	DO 700 I=1,NSEGS	047540	0000
C	N=SEQUENCE NUMBER OF SHAFT SEGMENT	047550	0000
	N=I-1+NSEGI	047560	0000
	MEX=B(N,7)	047570	0000
	SSEGL=B(N,35)	047580	0000
C	CHECK FOR SHAFT CONSTRUCTED IN CUT AND COVER	047590	0000
	IF(MEX.EQ.0) ARSLT=0.	047600	0000
	IF(MEX.EQ.0) GO TO 700	047610	0000
	STABNO=B(N,24)	047620	0000
C	D=DEPTH TO MIDPOINT OF SHAFT SEGMENT	047630	0000
	D=B(N,36)	047640	0000
	AR=B(N,8)	047650	0000
	RQD=B(N,6)	047660	0000
	GI=B(N,5)	047670	0000
C	FU IS AN INFLOW ADVANCE RATE FACTOR=1.0 IN DRY SHAFTS,.5 IN WET	047680	0000
	IF(GI.LT.1.) GO TO 440	047690	0000
C	SHAFT IS WET	047700	0000
	FU=0.5	047710	0000
	GO TO 450	047720	0000
C	SHAFT IS DRY	047730	0000
440	FU=1.0	047740	0000
450	BE=B(N,29)	047750	0000
	RS=B(N,5)	047760	0000
	IF(MEX.EQ.MEXP) GO TO 410	047770	0000
C	THIS IS FIRST SEGMENT IN SHAFT OR EXCAVATION METHOD HAS CHANGED	047780	0000
	BINSAR=0.	047790	0000
	GO TO 420	047800	0000
C	EXCAVATION IS SAME AS IN PREVIOUS SEGMENT	047810	0000
410	BINSAR=PINSAR-.05	047820	0000
	IF(BINSAR.LT.0.) BINSAR=0.	047830	0000
420	IF(AR.GT.0.) ARSLT=AR	047840	0000
	IF(AR.GT.0.) GO TO 500	047850	0000
C	-----	047860	0000
C	AN ULTIMATE ADVANCE RATE HAS NOT BEEN SPECIFIED,MUST COMPUTE ONE	047870	0000
C	COMPUTE SYSTEM ADVANCE RATES IN FEET/24 HOURS	047880	0000
C	CHECK FOR METHOD OF EXCAVATION	047890	0000
	IF(MEX.EQ.1 .OR. MEX.EQ.4) GO TO 1610	047900	0000
	IF(MEX.EQ.3) GO TO 1600	047910	0000
C	-----	047920	0000
C	MOLE IN ROCK	047930	0000
C	ADVANCE RATE EQUATION NOT GOOD FOR ROCK STRENGTH BELOW 3000 PSI	047940	0000
	IF(RS.LT.3000., RS=3000.	047950	0000
	ARSLT=(5000000/(BE*RS))*(.5+RQD/200.)*FU	047960	0000
	GO TO 1650	047970	0000
C	MOLE IN SOFT GROUND	047980	0000
C	-----	047990	0000
1600	ARSLT=(25.-4.*STABNO)*(.1.-D/6000.)	048000	0000
	GO TO 1650	048010	0000
C	CONVENTIONAL EXCAVATION IN ROCK OR HAND EXCAVATION IN SOFT GROUND	048020	0000
1610	IF(MEX.EQ.4) GO TO 1620	048030	0000
C	CONVENTIONAL EXCAVATION IN ROCK	048040	0000
	ARSLT=.05*FU*(RQD+100.)*(1.-D/6000.)	048050	0000
	GO TO 1650	048060	0000
C	HAND EXCAVATION IN SOFT GROUND	048070	0000
1620	ISHAPS=SHAFT(NSHAFT,16)	048080	0000

(Continued)

COSTFN Listing (Cont Inued)

	IF(ISHAPS.EQ.1) SFA=0.785	048090	0000
	IF(ISHAPS.EQ.2) SFA=1.0	048100	0000
	ARSULT=(10.-STABNO)*(1.-D/6000.)*0.785/SFA	048110	0000
C	-----	048120	0000
C	CHECK FOR SOFT GROUND FACE STABILIZATION BY GROUND INJECTIONS	048130	0000
1650	IF(MSTAB.EQ.3) GO TO 1660	048140	0000
	GO TO 1700	048150	0000
C	GROUND INJECTIONS ARE USED.CHECK FOR APPLICATION FROM INSIDE SEG.	048160	0000
1660	IF(D.LE.200.) GO TO 1700	048170	0000
C	GROUND INJECTIONS ARE MADE FROM WITHIN SEGMENT AND SLOWS ADVANCE	048180	0000
	ARSULT=100./(100.+ARSULT)*ARSULT	048190	0000
C	CONVERT COMPUTED ADVANCE RATES TO FEET/HOURS WORKED. INPUT RATES	048200	0000
C	ARE ALREADY IN FEET/HOURS WORKED	048210	0000
1700	HOURS=SHAFT(NSHAFT,17)	048220	0000
	ARSULT=ARSULT*HOURS/24.	048230	0000
C	-----	048240	0000
500	IF(SSEGL.LE.25.*(1.-BINSAR**2.)*ARSULT) GO TO 520	048250	0000
C	ULTIMATE ADVANCE RATE IS ATTAINED	048260	0000
	ARFAC=SSEGL/(25.*(1.-BINSAR)**2. *ARSULT+SSEGL)	048270	0000
	PINSAR=1.0	048280	0000
	GO TO 640	048290	0000
C	ULTIMATE ADVANCE RATE NEVER ATTAINED, SEGMENT TOO SHORT	048300	0000
520	ARFAC=.5*(BINSAR+SQRT(BINSAR**2.+.04*SSEGL/ARSULT))	048310	0000
	PINSAR=SQRT(BINSAR**2.+.04*SSEGL/ARSULT)	048320	0000
640	MEXP=MEX	048330	0000
C	COMPUTE AND STORE AVERAGE ADVANCE RATE FOR EACH SEGMENT	048340	0000
	B(N,39)=ARSULT	048350	0000
700	B(N,8)=ARSULT*ARFAC	048360	0000
800	CONTINUE	048370	0000
C	-----	048380	0000
	RETURN	048390	0000
	END	048400	0000
	SUBROUTINE CONSTM (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,	048410	0000
	INTRMAX)	048415	
C	-----	048420	0000
C	-----	048430	0000
C	THIS SUBROUTINE CALCULATES SEGMENT CONSTRUCTION TIMES INCLUDING	048440	0000
C	TIME FOR LINING	048450	0000
C	-----	048460	0000
	COMMON /BASIC/ NSS,NTS	048470	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	048480	0000
1	TRDATA(INTRMAX,23)	048490	0000
C	-----	048500	0000
	-----	048510	0000
C	-----	048520	0000
C	CALCULATE CONSTRUCTION TIME FOR TUNNEL SEGMENTS	048530	0000
	DO 50 I=1,NTS	048540	0000
C	NEXT LINE SETS VERY HIGH LINING ADVANCE RATE FOR UNLINED AND	048550	0000
C	SHOTCRETED TUNNEL SEGMENTS WHICH RESULTS IN PRACTICALLY ZERO	048560	0000
C	CONSTRUCTION TIME IN THESE SEGMENTS. TIME FOR SHOTCRETING IS ZERO	048570	0000
C	BECAUSE IT IS PLACED IMMEDIATELY AFTER EXCAVATION	048580	0000
	AL=10.E30	048590	0000
	NTSTYP=A(I,16)	048600	0000
	NREACH=A(I,4)	048610	0000
	HOURS=TRDATA(NREACH,8)	048620	0000
	DAYS=TRDATA(NREACH,9)	048630	0000

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COSTUN Listing (Continued)

	IF (NTSTYP.GT.1) GO TO 40	048640	0000
	LINING=A(I,10)	048650	0000
	IF(LINING.EQ.1) AL=3*HOURS	048660	0000
40	AR=A(I,8)	048670	0000
	TSEGL=A(I,45)	048680	0000
50	A(I,50)=(TSEGL/AR+TSEGL/AL)*7./DAYS	048690	0000
C	-----	048700	0000
C	CALCULATE CONSTRUCTION TIME FOR SHAFT SEGMENTS	048710	0000
	DO 100 I=1,NSS	048720	0000
C	NEXT LINE SETS VERY HIGH LINING ADVANCE RATE FOR UNLINED AND	048730	0000
C	SHOTCRETED SHAFT SEGMENTS WHICH RESULTS IN PRACTICALLY ZERO	048740	0000
C	CONSTRUCTION TIME IN THESE SEGMENTS. TIME FOR SHOTCRETING IS ZERO	048750	0000
C	BECAUSE IT IS PLACED IMMEDIATELY AFTER EXCAVATION	048760	0000
	AL=10.E30	048770	0000
	NSSTYP=B(I,15)	048780	0000
	NSHAFT=B(I,1)	048790	0000
	ISHAPS=SHAFT(NSHAFT,16)	048800	0000
	HOURS=SHAFT(NSHAFT,17)	048810	0000
	DAYS=SHAFT(NSHAFT,18)	048820	0000
	IF (NSSTYP.GT.1) GO TO 80	048830	0000
	LINING=B(I,10)	048840	0000
	IF(LINING.EQ.1) AL=2.*HOURS	048850	0000
80	AR=B(I,8)	048860	0000
	SSEGL=B(I,35)	048870	0000
C	NO CONSTRUCTION TIME FOR CUT AND COVER OR DUMMY SHAFT	048880	0000
	IF(NSSTYP.EQ.3.OR.ISHAPS.EQ.0) AR=10.E30	048890	0000
100	B(I,40)=(SSEGL/AR+SSEGL/AL)*7./DAYS	048900	0000
C	-----	048910	0000
	RETURN	048920	0000
	END	048930	0000
	SUBROUTINE PUMPH (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,	048940	0000
	INTRMAX)	048945	
C	-----	048950	0000
C	-----	048960	0000
C	THIS SUBROUTINE COMPUTES PUMPING HEIGHTS FOR TUNNEL SEGMENTS	048970	0000
C	-----	048980	0000
	COMMON /BASIC/ NSS,NTS	048990	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	049000	0000
	1 TRDATA(INTRMAX,23)	049010	0000
C	-----	049020	0000
	DO 200 I=1,NTS	049030	0000
	NREACH=A(I,4)	049040	0000
	NTSTYP=A(I,16)	049050	0000
	IF(NTSTYP.EQ.3) GO TO 100	049060	0000
C	ROCK OR SOFT GROUND	049070	0000
C	COMPUTE PUMPING HEIGHTS. PUMPING HEIGHT EQUALS SHAFT DEPTH OR	049080	0000
C	DIFFERENCE IN ELEVATION FROM TOP OF SHAFT TO MIDPOINT OF TUNNEL	049090	0000
C	SEGMENT, WHICHEVER IS GREATER	049100	0000
	NSHAFT=TRDATA(NREACH,1)	049110	0000
	NPTS=SHAFT(NSHAFT,2)	049120	0000
	ELTS=CNP(NPTS,2)	049130	0000
	NPL=A(I,2)	049140	0000
	NPR=A(I,3)	049150	0000
	ELNPL=CNP(NPL,2)	049160	0000
	ELNPR=CNP(NPR,2)	049170	0000
C	ELEVATION AT MIDPOINT OF TUNNEL SEGMENT	049180	0000
	ELAUG=(ELNPL+ELNPR)/2.	049190	0000
		049200	0000

(Continued)

COSTUN Listing (Continued)

	PH=ELTS-ELAVG	049210	0000
C	SET HH EQUAL TO MUCK HOISTING HEIGHT(SHAFT DEPTH)	049220	0000
	HH=SHAFT(NSHAFT,8)	049230	0000
	IF(HH.GE.PH) PH=HH	049240	0000
	GO TO 150	049250	0000
C	CUT AND COVER	049260	0000
100	D10=A(I,19)	049270	0000
	IF(D10.LE.0.005) PH=0	049280	0000
	IF(D10.LE.0.005) GO TO 150	049290	0000
	ELROCK=A(I,27)	049300	0000
	IWATER=A(I,23)	049310	0000
	ELIMP=A(I,24)	049320	0000
	NPLS=A(I,17)	049330	0000
	NPRS=A(I,18)	049340	0000
	ELNPLS=CNP(NPLS,2)	049350	0000
	ELNPRS=CNP(NPRS,2)	049360	0000
	ELSURF=(ELNPLS+ELNPRS)/2.	049370	0000
	DROCK=ELSURF-ELROCK	049380	0000
	DTRNCH=A(I,52)	049390	0000
	MEX=A(I,7)	049400	0000
	ISUPPT=A(I,26)	049410	0000
	ELWATR=A(I,14)	049420	0000
	DSLURY=A(I,38)	049430	0000
C	PH=THE SMALLER OF (ELSURF-ELIMP) AND DTRNCH, EXCEPT FOR SUMP	049440	0000
C	PUMPING, FOR WHICH PH=DTRNCH	049450	0000
	IF(DTRNCH.GE.ELSURF-ELIMP) PH=ELSURF-ELIMP	049460	0000
	IF(DTRNCH.LT.ELSURF-ELIMP) PH=DTRNCH	049470	0000
	IF(IWATER.EQ.0 .OR. ISUPPT.EQ.5 .AND. DROCK.LT.DTRNCH)PH=DTRNCH	049480	0000
	IF(IWATER.EQ.0 .AND. ISUPPT.EQ.6 .AND. DSLURY.GE.ELSURF-ELIMP) PH=0	049490	0000
	IF(ELWATR.LT.ELSURF-DTRNCH) PH=0	049500	0000
C	STORE PUMPING HEIGHT	049510	0000
150	A(I,57)=PH	049520	0000
200	CONTINUE	049530	0000
C	-----	049540	0000
	RETURN	049550	0000
	END	049560	0000
	SUBROUTINE PUMPRT (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,	049570	0000
	INTRMAX)	049575	
C	-----	049580	0000
C	-----	049590	0000
C	FLOW RATE TO BE PUMPED FROM TUNNEL AND DEWATERING FOR TUNNELS	049600	0000
C	AND SHAFTS.	049610	0000
C	-----	049620	0000
C	-----	049630	0000
	COMMON /BASIC/ NSS,NTS	049640	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	049650	0000
1	TRDATA(NTRMAX,23)	049660	0000
C	-----	049670	0000
C	*****	049680	0000
C	TUNNELS	049690	0000
C	*****	049700	0000
	DO 400 NREACH=1,NTRMAX	049710	0000
	IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 400	049720	0000
	NRSEG1=TRDATA(NREACH,5)	049730	0000
	NSEGS=TRDATA(NREACH,6)	049740	0000
	NSEGSA=IABS(NSEGS)	049750	0000
		049760	0000
		049770	0000

(Continued)

COSTUN Listing (Continued)

C	INITIALIZE VALUES	049780 0000
	FLRT=0.	049790 0000
	TUBE=0.0	049800 0000
	ZZ=0.0	049810 0000
	Z=0.	049820 0000
	DO 300 I=1,NSEGS	049830 0000
C	N=SEQUENCE NUMBER OF TUNNEL SEGMENT	049840 0000
	IF(NSEGS.GT.0) N=NRSEGI+I-1	049850 0000
	IF(NSEGS.LT.0) N=NRSEGI-I+1	049860 0000
	NTSTYP=A(N,16)	049870 0000
	PERM=A(N,25)	049880 0000
	DIO=A(N,19)	049890 0000
	IWATER=A(N,23)	049900 0000
	NSTAB=A(N,31)	049910 0000
	BE=A(N,39)	049920 0000
	ELROCK=A(N,27)	049930 0000
	MEX=A(N,7)	049940 0000
	ELWATR=A(N,14)	049950 0000
	NPL=A(N,2)	049960 0000
	NPR=A(N,3)	049970 0000
	ELNPL=CNP(NPL,2)	049980 0000
	ELNPR=CNP(NPR,2)	049990 0000
	ELAUG=(ELNPL+ELNPR)/2.	050000 0000
	IF(NTSTYP.EQ.3) GO TO 200	050010 0000
C	-----	050020 0000
C	ROCK OR SOFT GROUND TUNNELS	050030 0000
C	-----	050040 0000
	HEADING INFLOW AND RESIDUAL FLOW IN TUNNELS	050050 0000
	GI=A(N,9)	050060 0000
	ELBOTM=ELAUG-BE/2.	050070 0000
	ISHAPE=TRDATA(NREACH,3)	050080 0000
	IF(ISHAPE.EQ.3) ELBOTM=ELAUG-BE/4.	050090 0000
C	IF GROUNDWATER BELOW TUNNEL, GI = 0	050100 0000
	IF(ELWATR.LT.ELBOTM) GI=0.	050110 0000
	IF(NTSTYP.EQ.2) GO TO 140	050120 0000
C	ROCK TUNNELS	050130 0000
C	ESTABLISH RESIDUAL INFLOW(GPM/FT) AND INFLOW AT FACE FOR PUMPING	050140 0000
	IN GPM	050150 0000
	IF(GI.GE.100.) GO TO 135	050160 0000
	GIR=0.001*GI	050170 0000
	GIF=GI	050180 0000
	GO TO 155	050190 0000
135	GIR=0.1	050200 0000
	GIF=100.	050210 0000
	GO TO 155	050220 0000
C	SOFT GROUND TUNNELS	050230 0000
140	GIF=GI	050240 0000
	GIR=0.	050250 0000
155	A(N,60)=GIR	050260 0000
	R=FLRT	050270 0000
	TSEGL=A(N,45)	050280 0000
	FLRT=0.5*GIR*TSEGL	050290 0000
C	AVERAGE FLOW TO BE PUMPED AND CHARGED TO NTH SEGMENT	050300 0000
	FLOW=Z+R+FLRT+GIF	050310 0000
	A(N,59)=FLOW	050320 0000
	Z=FLOW-GIF	050330 0000
C	THE FOLLOWING WILL DETERMINE THE LENGTH OF PIPE REQUIRED	050340 0000
C	FOR THE SEGMENT WHEN PUMPING UPHILL. IT IS ASSUMED THAT NO PIPE	050350 0000

(Continued)

C	IS REQUIRED WHEN THE WATER MAY RUN DOWN THE SEGMENT IN THE	050360	0000
C	DIRECTION OF THE EXIT SHAFT.	050370	0000
	NPL=A(N,2)	050380	0000
	NPR=A(N,3)	050390	0000
	ELUD=CNP(NPR,2)-CNP(NPL,2)	050400	0000
C	SLOPE IS POSITIVE WHEN UPHILL IN THE DIRECTION OF HEADING ADVANCE	050410	0000
C	SS= SIGN OF THE SLOPE(ACTUAL VALUE IS IMMATERIAL)	050420	0000
	SS=ELUDXNSEQS	050430	0000
C	ESTABLISH THE PIPE LENGTH REQUIRED	050440	0000
	PIPE=0.0	050450	0000
	IF(SS.LT.0) PIPE=0.5*TSGL	050460	0000
C	DETERMINE THE CUMULATIVE PIPE LENGTHS REQUIRED	050470	0000
	A(N,58)=ZZ+TUBE+PIPE	050480	0000
	TUBE=PIPE	050490	0000
	ZZ=A(N,58)	050500	0000
	IF(NTSTYP.EQ.2) GO TO 160	050510	0000
C	ROCK TUNNELS	050520	0000
	GO TO 300	050530	0000
C		050540	0000
C		050550	0000
C	DEWATERING FOR SOFT GROUND TUNNELS	050560	0000
160	IF(MSTAB.NE.2 .OR.ABS(PERM).LE. 0.0006) GO TO 250	050570	0000
	HEADU=0	050580	0000
	ELIMP=A(N,24)	050590	0000
C	IF DEWATERING METHOD USED, WATER TABLE ABOVE IMPERVIOUS LAYER, AND	050600	0000
C	WATER TABLE ABOVE ELAUG, THEN SET FOLLOWING VALUES	050610	0000
	IF(ELIMP.GE.ELBOTM) DRAWDN=ELWATR-ELIMP	050620	0000
	IF(ELIMP.LT.ELBOTM) DRAWDN=ELWATR-ELBOTM	050630	0000
	DIMP=ELBOTM-ELIMP	050640	0000
	GO TO 210	050650	0000
C	-----	050660	0000
C	CUT AND COVER DEWATERING	050670	0000
C	-----	050680	0000
200	NPLS=A(N,17)	050690	0000
	NPRS=A(N,18)	050700	0000
	ELNPLS=CNP(NPLS,2)	050710	0000
	ELNPRS=CNP(NPRS,2)	050720	0000
	ELSURF=(ELNPLS+ELNPRS)/2.	050730	0000
	IF(D10.LE.0.005) GO TO 250	050740	0000
	ELIMP=A(N,24)	050750	0000
	DTRNCH=A(N,52)	050760	0000
	ISUPPT=A(N,26)	050770	0000
	PERM=ABS(PERM)	050780	0000
	IF(ISUPPT.NE.6 .OR. IWATER.EQ.1) GO TO 205	050790	0000
C	CHECK FOR SLURRY WALL PENETRATING IMPERVIOUS LAYER	050800	0000
	DSLURY=A(N,38)	050810	0000
	IF(DSLURY.GE.ELSURF-ELIMP.OR.DSLURY.GE.ELSURF-ELROCK) GO TO 250	050820	0000
205	HEADU=-7.X(ALOG10(PERM)+1.)	050830	0000
	IF(HEADU.GT.21.) HEADU=21.	050840	0000
	IF(HEADU.LT.0.0) HEADU=0.	050850	0000
C	HEADU=0 FOR SUMP PUMPING	050860	0000
	IF(IWATER.EQ.0.OR. ISUPPT.EQ.5.AND.ELROCK.GT.ELSURF-DTRNCH)HEADU=0	050870	0000
	DRAWDN=DTRNCH-(ELSURF-ELWATR)	050880	0000
	DIMP=ELSURF-ELIMP-DTRNCH	050890	0000
	IF(DIMP.LT.0.0) DRAWDN=ELWATR-ELIMP	050900	0000
210	IF(DIMP.LT.0.) DIMP=0	050910	0000
C	DEWATERING IS NOT NEEDED IF GROUNDWATER BELOW BOTTOM OF EXC.	050920	0000
	IF(DRAWDN.LE.0.) GO TO 250	050930	0000

(Continued)

COSTEN Listing (Continued)

	HEAD=DRAWDN+DIMP+HEADU	050940	0000
	PERM=ABS(PERM)	050950	0000
	FLOWDU=0.75*(0.73+0.27*(HEAD-DIMP)/HEAD)*(HEAD**2-DIMP**2)	050960	0000
	1/(HEAD-SQRT(HEAD*DIMP))*PERM	050970	0000
	IF(IWATER.EQ.0) GO TO 240	050980	0000
C	IS IT SOLDIER PILE WITH LAGGING AND ROCK LINE ABOVE TRENCH BOTTOM	050990	0000
	IF(ISUPPT.NE.5) GO TO 215	051000	0000
	IF(ELROCK.GT.ELSURF-DTRNCH) GO TO 240	051010	0000
C	WELL CAPACITY AND NUMBER OF WELLS	051020	0000
215	IF(FLOWDU.LE.0.7) GO TO 220	051030	0000
	IF(FLOWDU.GT.400.) GO TO 230	051040	0000
	FLOWL=15.*FLOWDU**1.2	051050	0000
	WELLSP=15.*FLOWDU**0.2	051060	0000
	GO TO 235	051070	0000
220	FLOWL=10	051080	0000
	WELLSP=10	051090	0000
	GO TO 235	051100	0000
230	FLOWL=20000	051110	0000
	WELLSP=20000/FLOWDU	051120	0000
235	WELLS=2./WELLSP	051130	0000
	GO TO 260	051140	0000
C	STORE FLOW FROM SUMP PUMPS	051150	0000
240	A(N,61)=FLOWDU**2.	051160	0000
	WELLS=0	051170	0000
	A(N,68)=WELLS	051180	0000
	GO TO 300	051190	0000
250	FLOWL=0	051200	0000
	WELLS=0	051210	0000
C	STORE WELL CAPACITY AND NUMBER OF WELLS PER FT OF TUNNEL	051220	0000
260	A(N,61)=FLOWL	051230	0000
	A(N,68)=WELLS	051240	0000
300	CONTINUE	051250	0000
400	CONTINUE	051260	0000
C	*****	051270	0000
C	SHAFTS-- DEWATERING ONLY	051280	0000
C	*****	051290	0000
C	*****	051300	0000
	DO 700 NSHAFT=1,NSMAX	051310	0000
	IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 700	051320	0000
	NSSEG1=SHAFT(NSHAFT,1)	051330	0000
	NSEGS=SHAFT(NSHAFT,4)	051340	0000
	DO 600 I=1,NSEGS	051350	0000
	N=NSSEG1+I-1	051360	0000
	NSSTYP=B(N,15)	051370	0000
	PERM=B(N,23)	051380	0000
	MSTAB=B(N,25)	051390	0000
	MEX=B(N,7)	051400	0000
	BE=B(N,29)	051410	0000
	IF(NSSTYP.NE.2) GO TO 550	051420	0000
C	SOFT GROUND SHAFTS	051430	0000
	IF(MSTAB.NE.2 .OR. ABS(PERM).LE. 0.0006) GO TO 550	051440	0000
	ELWATR=B(N,13)	051450	0000
	NPB=B(N,4)	051460	0000
	ELNPB=CHP(NPB,2)	051470	0000
C	DEWATERING NOT NEEDED IF GROUNDWATER BELOW BOTTOM OF SHAFT SEGMENT	051480	0000
	IF(ELWATR.LE.ELNPB) GO TO 550	051490	0000
	NPTS=SHAFT(NSHAFT,2)	051500	0000
		051510	0000

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COSTUN Listing (Continued)

	ELSURF=CNP(NPTS,2)	051520	0000
	ISHAP=SHAFT(NSHAFT,16)	051530	0000
	ELIMP=B(N,20)	051540	0000
	DRAUDN=ELUATR-ELNPB	051550	0000
	DIMP=ELNPB-ELIMP	051560	0000
	HEAD=DRAUDN+DIMP	051570	0000
	PERM=ABS(PERM)	051580	0000
	FLOUDD=0.75*(0.73+0.27*(HEAD-DIMP)/HEAD)*((HEAD**2-DIMP**2)	051590	0000
	1/(HEAD-SQRT(HEAD*DIMP))*PERM	051600	0000
	WELLS=3	051610	0000
	SFP=3.14	051620	0000
	IF(ISHAP.EQ.2) SFP=4	051630	0000
	WELLSP=SFP*(BE+20.)/3.	051640	0000
	FLOWL=FLOUDD*WELLSP	051650	0000
	GO TO 560	051660	0000
C	ROCK OR CUT AND COVER SHAFTS	051670	0000
550	FLOWL=0	051680	0000
C	STORE WELL CAPACITY	051690	0000
560	B(N,42)=FLOWL	051700	0000
600	CONTINUE	051710	0000
700	CONTINUE	051720	0000
	RETURN	051730	0000
	END	051740	0000
	SUBROUTINE VOLUME (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,	051750	0000
	INTRMAX)	051755	
C	-----	051760	0000
C	-----	051770	0000
C	THIS SUBROUTINE COMPUTES THE EXCAVATED VOLUME PER LINEAR FOOT OF	051780	0000
C	TUNNEL AND SHAFT	051790	0000
C	-----	051800	0000
C	-----	051810	0000
	COMMON /BASIC/ NSS,NTS	051820	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	051830	0000
	1 TRDATA(NTRMAX,23)	051840	0000
C	-----	051850	0000
C	TUNNEL VOLUME INCLUDING OVERBREAK IN SOLID CUBIC YARDS/FOOT	051860	0000
	DO 10 I=1,NTS	051870	0000
	NTSTYP=A(I,16)	051880	0000
C	CHECK IF SEGMENT EXCAVATED BY CUT AND COVER	051890	0000
	IF(NTSTYP.EQ.3) GO TO 55	051900	0000
C	TUNNEL	051910	0000
	BOB=A(I,42)	051920	0000
	NREACH=A(I,4)	051930	0000
	ISHAPE=TRDATA(NREACH,3)	051940	0000
C	CHECK THE SHAPE OF TUNNEL	051950	0000
	IF(ISHAPE.EQ.1) SFA=0.785	051960	0000
	IF(ISHAPE.EQ.2) SFA=0.893	051970	0000
	IF(ISHAPE.EQ.3) SFA=0.425	051980	0000
	U=BOB**2*SFA/27.	051990	0000
	GO TO 10	052000	0000
C	-----	052010	0000
C	CUT AND COVER	052020	0000
55	BE=A(I,39)	052030	0000
	DTRNCH=A(I,52)	052040	0000
	NPLS=A(I,17)	052050	0000
	NPRS=A(I,18)	052060	0000
	SIDESL=A(I,53)	052070	0000
C	COMPUTE THE DEPTH OF ROCK	052080	0000

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      ELROCK=A(I,27)                                052090 0000
      ELSURF=0.5*(CNP(NPLS,2)+CNP(NPRS,2))          052100 0000
      DROCK=ELSURF-ELROCK                           052110 0000
C      COMPUTE THE EXCAVATED VOLUME IF CUT IS ENTIRELY IN SOIL
      UROCK=0.                                         052120 0000
      USOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27.           052130 0000
      IF(DROCK.GE.DTRNCH) GO TO 88                   052140 0000
C      COMPUTE THE EXCAVATED VOLUME IF CUT IS IN PART SOIL-PART ROCK
      UROCK=BE*(DTRNCH-DROCK)/27.                   052150 0000
      USOIL=(BE+DROCK*SIDESL)*DROCK/27.             052160 0000
      U=UROCK+USOIL                                   052170 0000
      A(I,51)=U                                       052180 0000
      10 A(I,51)=U                                   052190 0000
C      -----
C      SHAFT
      DO 20 I=1,NSS                                  052200 0000
      BOB=B(I,32)                                    052210 0000
      SFA=0.785                                       052220 0000
      NSHAFT=B(I,1)                                  052230 0000
      ISHAPS=SHAFT(NSHAFT,16)                        052240 0000
      NSSTYP=B(I,15)                                052250 0000
      IF(ISHAPS.EQ.2) SFA=1.                          052260 0000
      U=0.                                             052270 0000
      IF(ISHAPS.EQ.0) GO TO 20                        052280 0000
      IF(NSSTYP.NE.3) U=BOB**2*SFA/27.               052290 0000
      20 B(I,38)=U                                    052300 0000
      RETURN                                          052310 0000
      END                                            052320 0000
      SUBROUTINE EXCUOL (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,
      1 NTRMAX)                                       052330 0000
C      -----
C      CALCULATES THE EXCAVATED VOLUME TO EXIT FROM EACH SHAFT AND
C      LENGTH OF TRENCH TEMPORARILY LEFT OPEN IN CUT-AND-COVER EXCAVATION
C      -----
C      COMMON /BASIC/ NSS,NTS
C      DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),
      1 TRDATA(NTRMAX,23)                            052360 0000
C      -----
C      INITIALIZE TOTAL EXCAVATED VOLUME
      DO 100 N=1,NSMAX                                052370 0000
      SHAFT(N,9)=0.0                                  052380 0000
C      100 CALCULATE VOLUME FROM CUT AND COVER REACH
C      -----
      DO 1000 I=1,NTRMAX                             052390 0000
      IF (TRDATA(I,1).LT.0) GO TO 1000               052400 0000
      NRSEG1=TRDATA(I,5)                             052410 0000
      NTSTYP=A(NRSEG1,16)                             052420 0000
      IF(NTSTYP.NE.3) GO TO 1000                     052430 0000
      NSHAFT=TRDATA(I,1)                             052440 0000
      NSEGS=TRDATA(I,6)                             052450 0000
      DAYS=TRDATA(I,9)                               052460 0000
      NSEGSA=IABS(NSEGS)                             052470 0000
      UTEXC=0.                                         052480 0000
      UTBOX=0.                                         052490 0000
      PINSAR=0.                                       052500 0000
      M=NRSEG1                                         052510 0000
      1000

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COSTEN Listing (Continued)

	L=0	052660	0000
	UTDS=0.	052670	0000
1100	T1=0.	052680	0000
	L=L+1	052690	0000
	TSEGL =A(N,45)	052700	0000
	U =A(N,51)	052710	0000
	UBOX =A(N,54)	052720	0000
	AR =A(N, 8)	052730	0000
	ARTULT=A(N,49)	052740	0000
	LINING=A(N,10)	052750	0000
	CTTS1 =TSEGL/AR	052760	0000
C	ADVANCE RATE FACTOR AT END POINTS OF SEGMENT	052770	0000
	BINSAR=PINSAR-0.05	052780	0000
	IF(BINSAR.LT.0.) BINSAR=0.	052790	0000
	TMULT=(1.-BINSAR)/0.02	052800	0000
	PINSAR=BINSAR+0.02*CTTS1	052810	0000
	IF(PINSAR.GT.1.)PINSAR=1.	052820	0000
C	TIME REQUIRED FOR TRENCH TO BE LEFT OPEN	052830	0000
	IF(LINING.EQ.1) TIMEOP=30.*DAYS/7.*10.	052840	0000
	IF(LINING.EQ.3) TIMEOP=10.	052850	0000
	UTEXC=UTEXC+UTSEGL	052860	0000
	UTBOX=UTBOX+UBOX*ITSEGL	052870	0000
	IF(CTTS1.GT.TIMEOP) T1=CTTS1-TIMEOP	052880	0000
C	COMPUTE THE LENGTH OF OPEN WITHOUT BACKFILL	052890	0000
1200	IF(CTTS1.LE.TMULT) OPENT=ARTULT*(CTTS1-T1)*(BINSAR+0.01*(CTTS1+T1)	052900	0000
	1)	052910	0000
	IF(CTTS1.GT.TMULT) OPENT=ARTULT*(BINSAR*(TMULT-T1)+0.01*(TMULT**2	052920	0000
	1 -T1**2)+CTTS1-TMULT)	052930	0000
	IF(T1.GT.TMULT) OPENT=ARTULT*(CTTS1-T1)	052940	0000
C	CALCULATE VOLUME OF DISPOSAL AND BACKFILL	052950	0000
	UTDST=(0.1*UTEXC+UTBOX+(U-UBOX)*OPENT)/1.1	052960	0000
	UBFT=(U-UBOX)*OPENT	052970	0000
	T2=TIMEOP-CTTS1+T1	052980	0000
	PIN2=PINSAR	052990	0000
	N=N+NSEGS/NSEGS	053000	0000
	LL=L+1	053010	0000
C	CHECK IF THE NEXT SEGMENT IS INVOLVED	053020	0000
	IF(T2.LE.0.) GO TO 1500	053030	0000
C	CHECK FOR END OF REACH	053040	0000
1300	IF(LL.GT.NSEGS) GO TO 1500	053050	0000
	TSEGL =A(N,45)	053060	0000
	U2 =A(N,51)	053070	0000
	UBOX2 =A(N,54)	053080	0000
	AR =A(N, 8)	053090	0000
	ARTU2 =A(N,49)	053100	0000
	CTTS2 =TSEGL/AR	053110	0000
	BIN2=PIN2-0.05	053120	0000
	IF(BIN2.LT.0.) BIN2=0.	053130	0000
C	CHECK IF MORE SEGMENTS INVOLVED	053140	0000
	IF(T2.LE.CTTS2) GO TO 1400	053150	0000
	LL=LL+1	053160	0000
	T2=T2-CTTS2	053170	0000
	N=N+NSEGS/NSEGS	053180	0000
	UTDST=UTDST+U2*ITSEGL	053190	0000
	UBFT=UBFT+(U2-UBOX2)*ITSEGL	053200	0000
	PIN2=BIN2+0.02*CTTS2	053210	0000
	IF(PIN2.GT.1.) PIN2=1.	053220	0000
	OPENT=OPENT+TSEGL	053230	0000

(Continued)

COSTUM Listing (Continued)

	GO TO 1300	053240	0000
	TMULT2=(1.-BIN2)/0.02	053250	0000
C	COMPUTE LENGTH WITHOUT BACKFILL IN THE LAST SEGMENT OF OPEN	053260	0000
	IF(T2.LE.TMULT2) OPENT2=ARTU2*(BIN2+0.01*T2)	053270	0000
	IF(T2.GT.TMULT2) OPENT2=ARTU2*(BIN2*TMULT2+0.01*TMULT2**2	053280	0000
	1 +T2-TMULT2)	053290	0000
C	COMPUTE VOLUME OF DISPOSAL AND BACKFILL	053300	0000
	UTDST=UTDST+U2*OPENT2	053310	0000
	UBFT=UBFT+(U2-UBOX2)*OPENT2	053320	0000
	OPENT=OPENT+OPENT2	053330	0000
C	MAXIMUM VOLUME IN LENGTH 'OPEN'	053340	0000
1500	IF(UTDS.GT.UTDST) GO TO 1600	053350	0000
	UTDS=UTDST	053360	0000
	UBF=UBFT	053370	0000
	OPEN=OPENT	053380	0000
C	CHECK IF LAST SEGMENT OF REACH	053390	0000
1600	IF (L.GE.NSEGS) GO TO 2100	053400	0000
	IF(LL.GT.NSEGS) GO TO 1700	053410	0000
	T1=T1+1.	053420	0000
	IF(T1.LT.CTTS1) GO TO 1200	053430	0000
	M=M+NSEGS/NSEGS	053440	0000
	GO TO 1100	053450	0000
C	-----	053460	0000
C	COMPUTE THE TOTAL VOLUME OF EXCAVATION AND BOX IN A REACH	053470	0000
1700	MM=M+1	053480	0000
	DO 2000 J=MM,N	053490	0000
	TSEGL=A(J,45)	053500	0000
	U=A(J,51)	053510	0000
	UBOX=A(J,54)	053520	0000
	UTEXC=UTEXC+U*TSEGL	053530	0000
2000	UTBOX=UTBOX+UBOX*TSEGL	053540	0000
2100	UDS=UTDS/UTEXC	053550	0000
	SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+UTDS	053560	0000
C	BACKFILL VOLUME	053570	0000
	UBACDS=UBF/1.1/(UTEXC-UTBOX)	053580	0000
	UBACEX=0.909-UBACDS	053590	0000
C	STORE VALUES IN ARRAY	053600	0000
	TRDATA(I,16)=OPEN	053610	0000
	TRDATA(I,21)=UDS	053620	0000
	TRDATA(I,22)=UBACEX	053630	0000
	TRDATA(I,23)=UBACDS	053640	0000
1000	CONTINUE	053650	0000
C	-----	053660	0000
C	CALCULATE VOLUME FROM TUNNEL SEGMENT	053670	0000
	DO 200 N=1,NTS	053680	0000
	NREACH=A(N,4)	053690	0000
	NSHAFT=TRDATA(NREACH,1)	053700	0000
	NTSTYP=A(N,16)	053710	0000
	IF(NTSTYP.EQ.3) GO TO 200	053720	0000
	U=A(N,51)	053730	0000
	TSEGL=A(N,45)	053740	0000
	SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+U*TSEGL	053750	0000
200	CONTINUE	053760	0000
C	-----	053770	0000
C	CALCULATE VOLUME FROM SHAFT SEGMENT	053780	0000
	DO 300 N=1,NSS	053790	0000
	NSHAFT=B(N,1)	053800	0000
	NSSTYP=B(N,15)	053810	0000

(Continued)

COSTIN Listing (Continued)

	IF(NSSTYP.EQ.3) GO TO 300	053820	0000
	U=B(N,38)	053830	0000
	SSEGL=B(N,35)	053840	0000
	SHAFT(NSHAFT,9)=SHAFT(NSHAFT,9)+U*SSEGL	053850	0000
300	CONTINUE	053860	0000
C	-----	053870	0000
	RETURN	053880	0000
	END	053890	0000
	SUBROUTINE MUCKLD(A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,	053900	0000
	INTRMAX)	053905	
C	-----	053910	0000
C	-----	053920	0000
C	CALCULATES REQUIRED MUCK LOADING RATES IN EACH SEGMENT AND	053930	0000
C	MAXIMUM RATE IN EACH REACH OR SHAFT BASED ON ULTIMATE ADVANCE RATE	053940	0000
C	-----	053950	0000
	COMMON /BASIC/ NSS,NTS	053960	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	053970	0000
	1 TRDATA(NTRMAX,23)	053980	0000
C	-----	053990	0000
C	MUCK LOADING RATE IN TUNNEL SEGMENTS AND MAXIMUM RATE IN REACH	054000	0000
	DO 400 NREACH=1,NTRMAX	054010	0000
	IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 400	054020	0000
C	-----	054030	0000
	HOURS=TRDATA(NREACH,8)	054040	0000
	NRSEG1=TRDATA(NREACH,5)	054050	0000
	NSEGS=TRDATA(NREACH,6)	054060	0000
	NSEGS=IABS(NSEGS)	054070	0000
C	-----	054080	0000
	RMLMAX=0	054090	0000
C	-----	054100	0000
	DO 300 I=1,NSEGS	054110	0000
C	N=SEQUENCE NUMBER OF TUNNEL SEGMENT	054120	0000
	IF(NSEGS.GT.0) N=NRSEG1+I-1	054130	0000
	IF(NSEGS.LT.0) N=NRSEG1-I+1	054140	0000
	NTSTYP=A(N,16)	054150	0000
	IF (NTSTYP.EQ.3) GO TO 300	054160	0000
	MEX=A(N,7)	054170	0000
	U=A(N,51)	054180	0000
	ARTULT=A(N,49)	054190	0000
C	CALCULATE MUCK LOADING RATE	054200	0000
	IF(MEX.EQ.1) GO TO 200	054210	0000
	RML=3.*XU*ARTULT/HOURS	054220	0000
	GO TO 250	054230	0000
200	IF(5.*HOURS/ARTULT.GE.2) RML=5.*XU	054240	0000
	IF(5.*HOURS/ARTULT.LT.2.) RML=2.*XU*ARTULT/HOURS	054250	0000
250	IF(RMLMAX.LT.RML) RMLMAX=RML	054260	0000
	A(N,48)=RML	054270	0000
300	CONTINUE	054280	0000
C	-----	054290	0000
350	TRDATA(NREACH,7)=RMLMAX	054300	0000
400	CONTINUE	054310	0000
C	-----	054320	0000
C	MUCK LOADING RATE IN SHAFT SEGMENTS AND MAXIMUM RATE IN SHAFTS	054330	0000
	DO 800 NSHAFT=1,NSMAX	054340	0000
	IF(SHAFT(NSHAFT,1).LE.-10.E29) GO TO 800	054350	0000
C	-----	054360	0000
	HOURS=SHAFT(NSHAFT,17)	054370	0000
		054380	0000

(Continued)

COSTUN Listing (Continued)

	NSEQ1=SHAFT(NSHAFT,1)	054350	0000
	NSEQS=SHAFT(NSHAFT,4)	054400	0000
C	RMLMAX=0	054410	0000
C	DO 700 I=1,NSEQS	054420	0000
	N=I-1+NSEQ1	054430	0000
C	N=SEQUENCE NUMBER OF SHAFT SEGMENT	054440	0000
C	CHECK FOR CUT AND COVER OR DUMMY SHAFT - NO RML COMPUTED	054450	0000
	MEX=B(N,7)	054460	0000
	IF(MEX.EQ.0) GO TO 700	054470	0000
	U=B(N,38)	054480	0000
	ARSULT=B(N,39)	054490	0000
	IF(MEX.EQ.1) GO TO 600	054500	0000
	RML=3.*U*ARSULT/HOURS	054510	0000
	GO TO 650	054520	0000
600	IF(5.*HOURS/ARSULT.GE.12.) RML=5.*U/6.	054530	0000
	IF(5.*HOURS/ARSULT.LT.12.) RML=2.*U*ARSULT/HOURS	054540	0000
650	IF(RMLMAX.LT.RML) RMLMAX=RML	054550	0000
	B(N,37)=RML	054560	0000
700	CONTINUE	054570	0000
C	750 SHAFT(NSHAFT,10)=RMLMAX	054580	0000
C	800 CONTINUE	054590	0000
	-----	054600	0000
	RETURN	054610	0000
	END	054620	0000
	SUBROUTINE AIRLOK(A,B,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NSSMAX,NPMAX,	054630	0000
	1 NSMAX,NTRMAX)	054640	0000
	-----	054650	0000
	-----	054660	0000
	-----	054670	0000
	-----	054680	0000
	THIS SUBROUTINE DETERMINES THE LOCATIONS OF AIR LOCKS AND COOLING	054690	0000
	PLANT IN A REACH AND COMPUTES THE COOLING AND VENTILATION	054700	0000
	REQUIREMENTS OF TUNNEL SEGMENTS AND MAXIMUM REQUIREMENT IN A REACH	054710	0000
	-----	054720	0000
	-----	054730	0000
	COMMON /BASIC/ NSS,NTS	054740	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),	054750	0000
	1 TRDATA(NTRMAX,23),CUMSL(NPMAX)	054760	0000
C	-----	054770	0000
	DO 200 J=1,NTRMAX	054780	0000
	IF(TRDATA(J,1).LT.0) GO TO 200	054790	0000
	ISHAPE=TRDATA(J,3)	054800	0000
	IF(ISHAPE.EQ.0) GO TO 200	054810	0000
C	INITIALIZATION	054820	0000
	NRSEQ1=TRDATA(J,5)	054830	0000
	NSEQS=TRDATA(J,6)	054840	0000
	NSHAFT=TRDATA(J,1)	054850	0000
	DTC=0.	054860	0000
	QT=0.	054870	0000
	AIRTEM=SHAFT(NSHAFT,11)	054880	0000
	NSEQSA=IABS(NSEQS)	054890	0000
	KOOL=0	054900	0000
	DTCA=0.	054910	0000
	CAUT=0.	054920	0000
	M=0	054930	0000
	N1=1	054940	0000
	NPBS=SHAFT(NSHAFT,3)	054950	0000

(Continued)

COSTUN Listing (Continued)

	MM-SHAFT(NSHAFT,8)	054960	0000
	NPLOCK=0	054970	0000
	IF(I\$SHAPE.EQ.1) SFA=0.785	054980	0000
	IF(I\$SHAPE.EQ.2) SFA=0.853	054990	0000
	IF(I\$SHAPE.EQ.3) SFA=0.425	055000	0000
C	DETERMINE THE STATION OF THE FARTHEST POINT OF COMPRESSED AIR	055010	0000
C	SEGMENT IN A REACH	055020	0000
	DO 50 N=1,NSEQSA	055030	0000
	IF(NSEQS.LT.0) GO TO 10	055040	0000
C	I = SEQUENCE NUMBER OF SEGMENT	055050	0000
	I=NRSEGL+N-1	055060	0000
	NPFPEND=A(I,3)	055070	0000
	GO TO 20	055080	0000
10	I=NRSEGL-N+1	055090	0000
	NPFPEND=A(I,2)	055100	0000
20	MSTAB=A(I,31)	055110	0000
	TSEGL=A(I,45)	055120	0000
	IF(MSTAB.NE.1) GO TO 50	055130	0000
	DTCA=DTCA+TSEGL	055140	0000
	CUMFCA=CUMSL(NPFPEND)	055150	0000
50	CONTINUE	055160	0000
C	-----	055170	0000
C	DETERMINE THE LOCATION OF AIR LOCK FOR A SEGMENT IN COMPRESSED AIR	055180	0000
	DO 100 N=1,NSEQSA	055190	0000
	IF (NSEQS.LT.0) GO TO 60	055200	0000
	I=NRSEGL+N-1	055210	0000
	NPFPEND=A(I,3)	055220	0000
	NPREND=A(I,2)	055230	0000
	NPS=A(I,17)	055240	0000
	GO TO 65	055250	0000
60	I=NRSEGL-N+1	055260	0000
	NPFPEND=A(I,2)	055270	0000
	NPREND=A(I,3)	055280	0000
	NPS=A(I,18)	055290	0000
65	BE=A(I,39)	055300	0000
	PH=A(I,57)	055310	0000
	TSEGL=A(I,45)	055320	0000
	DM=A(I,46)	055330	0000
	RTEMP=A(I,12)	055340	0000
	MSTAB=A(I,31)	055350	0000
	IF(MSTAB.NE.1) GO TO 85	055360	0000
	PERM=A(I,25)	055370	0000
	D10=SQRT(10.*ABS(PERM))	055380	0000
	IF(D10.LE.0.005) D10=0.005	055390	0000
C	-----	055400	0000
	M=M+1	055410	0000
C	COMPUTE VENTILATION QUANTITY FOR THE SEGMENT IN COMPRESSED AIR	055420	0000
	CAU=((28.5+10.*ALOG10(D10))*SFA)*BE**2	055430	0000
C	CHECK THE FIRST COMPRESSED AIR SEGMENT	055440	0000
	IF(M.NE.1) GO TO 70	055450	0000
C	CHECK IF COOLING PLANT FOR FIRST AIR LOCK TO BE MOVED FROM	055460	0000
C	SHAFT TO ABOVE THE LOCK	055470	0000
	IF(ABS(CUMFCA-CUMSL(NPDS))+MM.LE.12000..AND.DTC.GT.0.) GO TO 75	055480	0000
	GO TO 71	055490	0000
C	CHECK SEPARATION BETWEEN TWO COMPRESSED AIR SEGMENTS	055500	0000
70	IF(ABS(CUMSL(M-1)-CUMSL(NPREND)).GT.5000..AND.	055510	0000
	1 ABS(CUMFCA-CUMSL(NPREND)).GT.2000.) GO TO 71	055520	0000
C	CHECK THE STATIONING OF THE SEGMENT END POINT TO DETERMINE THE	055530	0000

(Continued)

COSTUN Listing (Continued)

C	POSITION THE AIR LOCK	055540	0000
	LOCK=IABS(NPLOCK)	055550	0000
	IF(ABS(CUMSL(NPFEND)-CUMSL(LOCK))+DTHLOK.LE.10000.) GO TO 80	055560	0000
	IF(ABS(CUMFCA-CUMSL(LOCK))+DTHLOK.LE.12000.) GO TO 80	055570	0000
C	STORE THE HEAT EXCHANGE AND COMPRESSED AIR QUANTITIES WITHIN	055580	0000
C	COMPRESSED AIR SEGMENTS.	055590	0000
71	N2=N-1	055600	0000
	DO 72 NN=N1,N2	055610	0000
	II=NRSEG1+(NN-1)*NSEGS/NSEGS	055620	0000
	A(II,35)=CAUT	055630	0000
72	A(II,37)=QT	055640	0000
	N1=N	055650	0000
	CAUT=0.	055660	0000
	KOOL=1	055670	0000
C	KOOL = INDICATOR FOR THE LOCATION OF COOLING PLANT	055680	0000
	QT=0.	055690	0000
C	SET UP THE LOCK	055700	0000
75	NPLOCK=NPEND	055710	0000
	DTHLOK=CNP(NPS,2)-CNP(NPLOCK,2)	055720	0000
	DLOCK=ABS(CUMSL(NPLOCK)-CUMSL(NP85))	055730	0000
C	COMPUTE THE LENGTH OF PIPE FOR COOLING IN COMPRESSED AIR SEGMENT	055740	0000
80	IF(KOOL.EQ.0) PUMPLT=5280.*DM+HM	055750	0000
	IF(KOOL.EQ.1) PUMPLT=5280.*DM-DLOCK+DTHLOK	055760	0000
C	NPLOCK = NEGATIVE IF COOLING PLANT OF FIRST AIR LOCK MOVED FROM	055770	0000
C	SHAFT TO TOP OF LOCK	055780	0000
	IF (KOOL.EQ.1.AND.N.EQ.1.AND.DTC.GT.0.) NPLOCK=-NPLOCK	055790	0000
C	COMPUTE THE QUANTITY OF COOLED AIR REQUIRED IN COMPRESSED AIR	055800	0000
C	SEGMENT	055810	0000
	Q=CAUX(74.00+0.031*PUMPLT)+SQRT(CAU)*PUMPLT	055820	0000
1	* (0.23+0.0454*(RTEMP-85.))+239.*PUMPLT	055830	0000
	IF(CAU.GT.CAUT) CAUT=CAU	055840	0000
	M=NPFEND	055850	0000
	GO TO 90	055860	0000
C	-----	055870	0000
C	COMPUTE QUANTITY OF COOLED AIR REQUIRED IN FREE AIR SEGMENT	055880	0000
85	IF (KOOL.EQ.1) DM=DM-DLOCK/5280.	055890	0000
	Q=SFA*BE**2*(150.*PH/(AIRTEM+460.))+0.03*5280.*DM+54.*AIRTEM	055900	0000
1	-4000.))+5280.*DM*SQRT(SFA*BE**2)*(0.35*RTEMP-29.))+2.4*DM*5280.	055910	0000
90	IF(Q.LE.0.) GO TO 95	055920	0000
	DTC=DTC+TSEGL	055930	0000
	IF(Q.GT.QT) QT=Q	055940	0000
C	STORE THE LOCK POSITION AND HEAT EXCHANGE QUANTITY	055950	0000
95	A(I,38)=Q	055960	0000
	A(I,36)=NPLOCK	055970	0000
C	CHECK THE LAST SEGMENT IN A REACH	055980	0000
	IF (N.NE.NSEGS) GO TO 100	055990	0000
	DO 99 NN=N1,N	056000	0000
	II=NRSEG1+(NN-1)*NSEGS/NSEGS	056010	0000
	A(II,35)=CAUT	056020	0000
99	A(II,37)=QT	056030	0000
100	CONTINUE	056040	0000
	TRDATA(J,14)=DTC	056050	0000
	TRDATA(J,15)=DTC	056060	0000
200	CONTINUE	056070	0000
	RETURN	056080	0000
	END	056090	0000
	SUBROUTINE CALCS (A,B,CNP,SHAFT,TRDATA,NTSMAX,NSSMAX,NPMAX,NSMAX,	056100	0000
	INTRMAX)	056105	

(Continued)

COSTUN Listing (Cont Inued)

C	-----	056110	0000
C	THIS SUBROUTINE OUTPUTS CALCULATED TUNNEL AND SHAFT DATA	056120	0000
C	-----	056130	0000
C	COMMON /BASIC/ NSS,NTS	056140	0000
C	COMMON /A/ LO,LI,PN,OM,LIST(40),TITLE(160),STABEG,ITYPE	056150	0000
C	COMMON /F/ IERROR,ISTOP	056160	0000
C	DIMENSION A(NTSMAX,68),B(NSSMAX,43),CNP(NPRAX,2),SHAFT(NSMAX,23),	056170	0000
C	1 TRDATA(NTRMAX,23)	056180	0000
C	*****	056190	0000
C	REFER TO COMMENT ON DOUBLE PRECISION LITERALS IN SUBROUTINE 4.	056200	0000
C	DOUBLE PRECISION TNONE,AIRPRS,DEWATR,GRDINJ,SUMP,STABIL	056210	0000
C	*****	056220	0000
C	DATA TNONE// NONE //,AIRPRS//AIRPRS//,DEWATR//DEWATR//,	056230	0000
C	1GRDINJ//GRDINJ//,SUMP// SUMP //	056240	0000
C	-----	056250	0000
C	OUTPUT CALCULATED TUNNEL DATA	056260	0000
C	ITYPE=1	056270	0000
C	NLINES=40	056280	0000
C	IPR=0	056290	0000
C	N=SEGMENT SEQUENCE NUMBER	056300	0000
C	DO 100 N=1,NTS	056310	0000
C	NLINES=NLINES+1	056320	0000
C	IF(LIST(4).EQ.1) GO TO 10	056330	0000
C	IF(NLINES.LT.40) GO TO 10	056340	0000
C	NLINES=0	056350	0000
C	WRITE(LO,3000)	056360	0000
C	WRITE(LO,3010)	056370	0000
C	10 NREACH=A(N,4)	056380	0000
C	NPL=A(N,2)	056390	0000
C	NPR=A(N,3)	056400	0000
C	NTSEG=A(N,1)	056410	0000
C	BE= A(N,39)	056420	0000
C	NTSTYP=A(N,16)	056430	0000
C	IF(NTSTYP.EQ.3) GO TO 40	056440	0000
C	-----	056450	0000
C	ISHAPE=TRDATA(NREACH,3)	056460	0000
C	MTM=TRDATA(NREACH,4)	056470	0000
C	HSLOPE=A(N,47)	056480	0000
C	IF(MTM.NE.3) GO TO 20	056490	0000
C	CHECK FOR MAXIMUM SLOPE FOR TRAIN	056500	0000
C	IF(ABS(HSLOPE).LE.0.05) GO TO 30	056510	0000
C	WRITE(LO,1020) NTSEG,NREACH	056520	0000
C	NLINES=NLINES +1	056530	0000
C	IERROR=1	056540	0000
C	GO TO 30	056550	0000
C	20 IF(MTM.NE.1) GO TO 30	056560	0000
C	-----	056570	0000
C	CHECK FOR TUNNEL CROWN HIGH ENOUGH TO HANDLE A TRUCK	056580	0000
C	IF(ISHAPE.LE.2.AND.BE.LT.16.) GO TO 25	056590	0000
C	IF(ISHAPE.EQ.3.AND.BE.LT.30.) GO TO 25	056600	0000
C	GO TO 30	056610	0000
C	25 WRITE(LO,1021) NTSEG,NREACH	056620	0000
C	NLINES=NLINES +1	056630	0000
C	IERROR=1	056640	0000
C	30 CONTINUE	056650	0000
C		056660	0000
C		056670	0000
C		056680	0000

(Continued)

COSTUN Listing (Continued)

C	-----	056690	0000
C	CHECK FOR TOO STEEP A SLOPE FOR MUCK HAUL BY TRUCK OR CONVEYOR	056700	0000
	IF(ABS(HSLOPE).LE.0.26) GO TO 32	056710	0000
	WRITE(LO,1023) NTSEG,NREACH	056720	0000
	NLINES=NLINES+1	056730	0000
	IERROR=1	056740	0000
C	-----	056750	0000
C	CHECK SOFT GROUND TUNNEL FOR ALL TRUCK IN COMPRESSED AIR SEGMENTS	056760	0000
32	IF(NTSTYP.EQ.1) GO TO 40	056770	0000
	MSTAB=A(N,31)	056780	0000
	MUST=A(N,32)	056790	0000
	IF(MSTAB.NE.1) GO TO 40	056800	0000
	IF(MUST.LT.3.OR.MTM.NE.1) GO TO 35	056810	0000
	IERROR=1	056820	0000
	WRITE(LO,1025) NTSEG,NREACH	056830	0000
	NLINES=NLINES+1	056840	0000
35	CONTINUE	056850	0000
	IF(MUST.LT.3.AND.MTM.EQ.1) WRITE(LO,1030) NTSEG,NREACH	056860	0000
	IF(MUST.LT.3.AND.MTM.EQ.1) MTM=4	056870	0000
	TRDATA(NREACH,4)=MTM	056880	0000
40	CONTINUE	056890	0000
	IF(LIST(4).EQ.1) GO TO 70	056900	0000
C	-----	056910	0000
C	CONVERT NODAL POINT STATIONING TO INTEGER VALUES	056920	0000
	STA=CNP(NPL,1)	056930	0000
	ISTA=STA/100.	056940	0000
	ISTA2=STA-ISTA*100	056950	0000
	ITENS=ISTA2/10.	056960	0000
	IHUNS=ISTA2-ITENS*10	056970	0000
	IHUNS=IABS(IHUNS)	056980	0000
	ICTTS=A(N,50)	056990	0000
	LSEGL=A(N,45)	057000	0000
	IPRML=TRDATA(NREACH,7)	057010	0000
	IFL=A(N,59)	057020	0000
	IPH=A(N,57)	057030	0000
	BOB=A(N,42)	057040	0000
	ARTULT=A(N,49)	057050	0000
	TL=A(N,11)*12.	057060	0000
	BFT=TRDATA(NREACH,2)	057070	0000
	AR=A(N,8)	057080	0000
C	-----	057090	0000
C	EXCAVATED VOLUMES	057100	0000
50	USOIL=0.0	057110	0000
	UROCK=0.0	057120	0000
	U=A(N,51)	057130	0000
	IF(NTSTYP.EQ.1) UROCK=U	057140	0000
	IF(NTSTYP.EQ.2) USOIL=U	057150	0000
	IF(NTSTYP.LT.3) GO TO 60	057160	0000
C	CUT AND COVER	057170	0000
	DTRNCH=A(N,52)	057180	0000
	NPLS=A(N,17)	057190	0000
	NPRS=A(N,18)	057200	0000
	SIDESL=A(N,53)	057210	0000
C	COMPUTE THE DEPTH OF ROCK	057220	0000
	ELROCK=A(N,27)	057230	0000
	ELSURF=0.5*(CNP(NPLS,2)+CNP(NPRS,2))	057240	0000
	DROCK=ELSURF-ELROCK	057250	0000
C	COMPUTE THE EXCAVATED VOLUME IF CUT IS ENTIRELY IN SOIL	057260	0000

(Continued)

COSTEN Listing (Continued)

	UADCK=0.	057273	0000
	USOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27.	057280	0000
	IF(DROCK.GE.DTRNCH) GO TO 60	057290	0000
C	COMPUTE THE EXCAVATED VOLUME IF CUT IS IN PART SOIL-PART ROCK	057300	0000
	UROCK=BE*(DTRNCH-DROCK)/27.	057310	0000
	USOIL=(BE+DROCK*SIDESL)*DROCK/27.	057320	0000
60	IUTR=UROCK	057330	0000
	IUTS=USOIL	057340	0000
C	-----	057350	0000
	IF(NTSTYP.EQ.1) GO TO 70	057360	0000
	ISUPPT=A(N,26)	057370	0000
	GAMMA=A(N,22)	057380	0000
	PERM=ABS(A(N,25))	057390	0000
	IFLOWL=A(N,61)	057400	0000
	STABNO=A(N,30)	057410	0000
	IF(NTSTYP.EQ.3) GO TO 65	057420	0000
C	-----	057430	0000
C	SOFT GROUND TUNNEL	057440	0000
	AIRPR=A(N,33)	057450	0000
	MSTAB=A(N,31)	057460	0000
	IF(MSTAB.EQ.0) STABIL=TNONE	057470	0000
	IF(MSTAB.EQ.1) STABIL=AIRPRS	057480	0000
	IF(MSTAB.EQ.2) STABIL=DEWATR	057490	0000
	IF(MSTAB.EQ.3) STABIL=GRDINJ	057500	0000
	GO TO 70	057510	0000
C	-----	057520	0000
C	CUT AND COVER	057530	0000
65	UL=A(N,55)	057540	0000
	SIDESL=A(N,53)	057550	0000
	WELLS=A(N,68)	057560	0000
	DSLURY=0.0	057570	0000
	SPDLT=0.0	057580	0000
	STABIL=TNONE	057590	0000
	IF(IFLOWL.GT.0) STABIL=SUMP	057600	0000
	IF(IFLOWL.GT.0.AND.WELLS.GT.0.0) STABIL=DEWATR	057610	0000
	OPEN=TRDATA(NREACH,16)	057620	0000
	UBACEX=TRDATA(NREACH,22)	057630	00.00
	UBACDS=TRDATA(NREACH,23)	057640	0000
	U=A(N,51)	057650	0000
	UBOX=A(N,54)	057660	0000
	BACKFL=(UBACEX+UBACDS)*(U-UBOX)*1.1	057670	0000
C	CHECK IF SEGMENT IN SAME REACH	057680	0000
70	IF(IPR.EQ.NREACH) GO TO 85	057690	0000
C	-----	057700	0000
C	CALCULATE CONSTRUCTION TIME FOR THE REACH (CTR)	057710	0000
	NSEGS=TRDATA(NREACH,6)	057720	0000
	NSEGS=IABS(NSEGS)	057730	0000
	HOURS=TRDATA(NREACH,8)	057740	0000
	DAYS=TRDATA(NREACH,9)	057750	0000
	CTR=0.0	057760	0000
	ALOCK=0.0	057770	0000
	ICTR=0	057780	0000
	MEXP=0	057790	0000
	SETUSH=0.0	057800	0000
	SETUPH=0.0	057810	0000
	SETUPR=0.0	057820	0000

(Continued)

COSTEN Listing (Continued)

	TIMEDU=0.0	057830	0000
	TIMECR=0.0	057840	0000
	L=0	057850	0000
	DO 730 I=1,NSEGS	057860	0000
	NN=N+I-1	057870	0000
	CTTS=A(NN,50)	057880	0000
	MEX=A(NN,7)	057890	0000
702	IF(MEX.GE.6) GO TO 705	057900	0000
C	SOFT GROUND OR ROCK TUNNEL	057910	0000
	CALL SETUP(MEX,MEXP,SETUSH,SETUPM,SETUPR,ITYPE)	057920	0000
	IF(I.EQ.1) NPLOCK=A(NN,36)	057930	0000
	IF(A(NN,36).EQ.0) GO TO 730	057940	0000
C	CALCULATE NUMBER OF AIR LOCK SETUPS	057950	0000
	IF(ALOCK.LT.1.) GO TO 703	057960	0000
	IF(A(NN,36).EQ.NPLOCK) GO TO 730	057970	0000
	ALOCK=ALOCK+0.25	057980	0000
	GO TO 704	057990	0000
703	ALOCK=1.	058000	0000
704	NPLOCK=A(NN,36)	058010	0000
	GO TO 730	058020	0000
C	-----	058030	0000
C	CUT AND COVER	058040	0000
705	ELWATR=A(NN,14)	058050	0000
	D10=A(NN,19)	058060	0000
	IWATER=A(NN,23)	058070	0000
	ELIMP=A(NN,24)	058080	0000
	PERM=A(NN,25)	058090	0000
	FLOUL=A(NN,61)	058100	0000
	NPLS=A(NN,17)	058110	0000
	NPRS=A(NN,18)	058120	0000
	DTRNCH=A(NN,52)	058130	0000
	ELROCK=A(NN,27)	058140	0000
	ELNPLS=CNP(NPLS,2)	058150	0000
	ELNPRS=CNP(NPRS,2)	058160	0000
C	CALCULATE THE EXTRA CURING TIME FOR CIP CONCRETE	058170	0000
	IF(L.LT.0) GO TO 708	058180	0000
	MM=NN	058190	0000
	IF(NSEGS.GT.0) MM=N+NSEGS-1	058200	0000
	LINING=A(MM,10)	058210	0000
	IF(LINING.EQ.1) GO TO 707	058220	0000
	CTR=CTR+CTTS	058230	0000
	GO TO 708	058240	0000
707	TIMECR=30.-CTR	058250	0000
	IF(TIMECR.LT.0.) TIMECR=0.	058260	0000
	L=-1	058270	0000
708	IF(D10.LE.0.005.OR.IWATER.EQ.0) GO TO 730	058280	0000
	IF(PERM.GT.0.0.AND.D10.GT.0.08) GO TO 709	058290	0000
	IF(PERM.LT.0.0.AND.ABS(PERM).GT.0.0006) GO TO 709	058300	0000
	TIMEDU=30.	058310	0000
	GO TO 730	058320	0000
709	ELSURF=0.5*(ELNPLS+ELNPRS)	058330	0000
	DWATER=ELSURF-ELWATR	058340	0000
	DRAWDN=DTRNCH-DWATER	058350	0000
	DROCK=ELSURF-ELROCK	058360	0000
	PERM=ABS(PERM)	058370	0000
	IF(DROCK.LT.DTRNCH.AND.ISUPPT.EQ.5) GO TO 730	058380	0000
C	CHECK IF WATER TABLE BELOW BASE OF CUT	058390	0000
	IF(DRAWDN.LE.0.) GO TO 730	058400	0000

(Continued)

COSTEN Listing (Continued)

	DIMP=ELSURF-ELIMP-DTRNCH	058413	0000
C	CHECK IF IMPERVIOUS LAYER ABOVE BASE OF CUT	058420	0000
	IF(DIMP.GE.0.0) GO TO 710	058430	0000
	DRAWDN=ELWATR-ELIMP	058440	0000
	DIMP=0.0	058450	0000
710	HEADU=-7.*(ALOG10(PERM)+1.)	058460	0000
C	CHECK IF VACUUM HEAD GREATER THAN 21 FEET	058470	0000
	IF(HEADU.GT.21.) HEADU=21.0	058480	0000
C	CHECK IF VACUUM HEAD LESS THAN 0 FEET	058490	0000
	IF(HEADU.LT.0.0) HEADU=0.0	058500	0000
	HEAD=DRAWDN+HEADU+DIMP	058510	0000
	PIPED=0.5*FLOWL**0.4	058520	0000
C	MINIMUM PIPE SIZE	058530	0000
	IF(PIPED.LT.1.) PIPED=1.	058540	0000
C	DRAWDOWN TIME	058550	0000
	EXPT=2.5*DRAWDN*ALOG10(240.*(HEAD-SQRT(HEAD*DIMP))/PIPED)/(DRAWDN	058560	0000
	1*HEADU)/(0.73+0.27*(DRAWDN+HEADU)/HEAD)-5.0	058570	0000
	TIMET=0.00267*PIPED**2*10.**EXPT/PERM/DRAWDN	058580	0000
C	CHECK FOR MAXIMUM SEGMENT DEWATERING TIME IN REACH	058590	0000
	IF(TIMEDU.LT.TIMET) TIMEDU=TIMET	058600	0000
730	ICTR=ICTR+CTTS	058610	0000
	ICTR=ICTR+14.*SETUSH+28.*SETUPM+7.*SETUPR+14.*ALOCK	058620	0000
C	-----	058630	0000
C	CHECK FOR CUT AND COVER REACH	058640	0000
	NTSTYP=A(N,16)	058650	0000
	IF(NTSTYP.EQ.3) GO TO 740	058660	0000
	TRDATA(NREACH,10)=SETUSH	058670	0000
	TRDATA(NREACH,11)=SETUPM	058680	0000
	TRDATA(NREACH,12)=SETUPR	058690	0000
	GO TO 750	058700	0000
740	ICTR=ICTR+70./DAYS+TIMECR+TIMEDU	058710	0000
	TRDATA(NREACH,14)=TIMEDU	058720	0000
750	IF(LIST(4).EQ.1) GO TO 100	058730	0000
	WRITE(LO,2222)	058740	0000
	NLINES=NLINES+1	058750	0000
	IF(NTSTYP.EQ.1) GO TO 73	058760	0000
	PERM=ABS(A(N,25))	058770	0000
	GAMMA=A(N,22)	058780	0000
	IFLOWL=A(N,61)	058790	0000
73	CONTINUE	058800	0000
C	-----	058810	0000
C	IF(NTSTYP.EQ.3) GO TO 80	058820	0000
	ROCK OR SOFT GROUND TUNNEL	058830	0000
	WRITE(LO,3001) NREACH,NTSEG,ISTA,ITENS,IMUNS,LSEGL,BFT,BE,BOB,AR,	058840	0000
	1ARTULT,TL,IUTS,IUTR,IFL,IPH,ICTTS,ICTR,IPRML,HOURS,DAYS	058850	0000
	IF(NTSTYP.EQ.1) GO TO 100	058860	0000

(Continued)

COSTUN Listing (Continued)

C	-----	058878	0000
C	SOFT GROUND TUNNEL	058880	0000
C	IF(MSTAB.NE.1) GO TO 75	058890	0000
C	AIR LOCK NODAL POINTS	058900	0000
	NPLOCK=A(N,36)	058910	0000
	STA=CNP(NPLOCK,1)	058920	0000
	ISTA=STA/100.	058930	0000
	ISTA2=STA-ISTA*100	058940	0000
	ITENS=ISTA2/10.	058950	0000
	IHUNS=ISTA2-ITENS*10	058960	0000
	IHUNS=IABS(IHUNS)	058970	0000
	WRITE(LO,3002) ISTA,ITENS,IHUNS,STABNO,STABIL,AIRPR,IFLOWL,GAMMA,	058980	0000
	1PERM	058990	0000
	NLINES=NLINES+1	059000	0000
	GO TO 100	059010	0000
C	AIR PRESSURE NOT USED	059020	0000
75	WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM	059030	0000
	NLINES=NLINES+1	059040	0000
	GO TO 100	059050	0000
C	-----	059060	0000
C	CUT AND COVER	059070	0000
80	WRITE(LO,3004) NREACH,NTSEG,ISTA,ITENS,IHUNS,LSEGL,AR,ARTULT,IUTS,	059080	0000
1	IUTR,IPH,ICTTS,ICTR,HOURS,DAYS	059090	0000
	IF(ISUPPT.EQ.5) SPDLT=A(N,38)	059100	0000
	IF(ISUPPT.EQ.6) DSLURY=A(N,38)	059110	0000
	WRITE(LO,3005) STABNO,STABIL,IFLOWL,GAMMA,PERM,UL ,BE,SIDESL,	059120	0000
	1DSLURY,SPDLT,BACKFL,OPEN	059130	0000
	NLINES=NLINES+1	059140	0000
	GO TO 100	059150	0000
C	-----	059160	0000
C	THIS SEGMENT IN SAME REACH AS PREVIOUS SEGMENT	059170	0000
85	IF(LIST(4).EQ.1) GO TO 100	059180	0000
	WRITE(LO,2150)	059190	0000
	NLINES=NLINES+1	059200	0000
C	-----	059210	0000
C	IF(NTSTYP.EQ.3) GO TO 95	059220	0000
C	ROCK OR SOFT GROUND TUNNEL	059230	0000
	WRITE(LO,3011) NTSEG,ISTA,ITENS,IHUNS,LSEGL,BFT,BE,BOB,AR,ARTULT,	059240	0000
1	TL,IUTS,IUTR,IFL,IPH,ICTTS	059250	0000
	IF(NTSTYP.EQ.1) GO TO 100	059260	0000
C	-----	059270	0000
C	SOFT GROUND TUNNEL	059280	0000
C	IF(MSTAB.NE.1) GO TO 90	059290	0000
C	AIR LOCK NODAL POINTS	059300	0000
	NPLOCK=A(N,36)	059310	0000
	STA=CNP(NPLOCK,1)	059320	0000
	ISTA=STA/100.	059330	0000
	ISTA2=STA-ISTA*100	059340	0000
	ITENS=ISTA2/10.	059350	0000
	IHUNS=ISTA2-ITENS*10	059360	0000

(Continued)

CONTINUED LISTING (Continued)

	IMUNS=IABS(IMUNS)	059370	0000
	WRITE(LO,3002) ISTA,ITENS,IMUNS,STABNO,STABIL,AIRPR,IFLOWL,GAMMA,	059380	0000
	1PERM	059390	0000
	NLINES=NLINES+1	059400	0000
	GO TO 100	059410	0000
C	AIR PRESSURE NOT USED	059420	0000
90	WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM	059430	0000
	NLINES=NLINES+1	059440	0000
	GO TO 100	059450	0000
C	-----	059460	0000
C	CUT AND COVER	059470	0000
95	WRITE(LO,3014) NTSEG,ISTA,ITENS,IMUNS,LSEGL,AR,ARTULT,IUTS,IUTR,	059480	0000
	1IPH,ICTTS	059490	0000
	IF(ISUPPT.EQ.5) SPDLT=A(N,38)	059500	0000
	IF(ISUPPT.EQ.6) DSLURY=A(N,38)	059510	0000
	WRITE(LO,3015) STABNO,STABIL,IFLOWL,GAMMA,PERM,UL ,BE,SIDSL,	059520	0000
	1DSLURY,SPDLT,BACKFL	059530	0000
	NLINES=NLINES+1	059540	0000
100	IPR=NREACH	059550	0000
	IF(LIST(4).EQ.0) WRITE(LO,2222)	059560	0000
C	-----	059570	0000
C	OUTPUT CALCULATED SHAFT DATA	059580	0000
C	IF(LIST(5).EQ.1) GO TO 300	059590	0000
	IPS=0	059600	0000
	ITYPE=2	059610	0000
	NLINES=40	059620	0000
	DO 200 N=1,NSS	059630	0000
	NLINES=NLINES+1	059640	0000
	IF(NLINES.LT.40) GO TO 102	059650	0000
	NLINES=0	059660	0000
	WRITE(LO,2000)	059670	0000
	WRITE(LO,2010)	059680	0000
102	NSHAFT=B(N,1)	059690	0000
	NSSEG=B(N,2)	059700	0000
	BE=B(N,29)	059710	0000
	BOB=B(N,32)	059720	0000
	ARSULT=B(N,39)	059730	0000
	IPRML=SHAFT(NSHAFT,10)	059740	0000
	ICTSS=B(N,40)	059750	0000
	IADS=SHAFT(NSHAFT,9)*0.00003	059760	0000
	LSEGL=B(N,35)	059770	0000
	NPB=B(N,4)	059780	0000
	IELNPB=CNP(NPB,2)	059790	0000
	TL=B(N,11)*12.	059800	0000
	R=B(N,8)	059810	0000
	NPORT=SHAFT(NSHAFT,23)	059820	0000
	NSSTYP=B(N,15)	059830	0000
C	-----	059840	0000
C	EXCAVATED VOLUMES	059850	0000
	UROCK=0.0	059860	0000
	USOIL=0.0	059870	0000
	U=B(N,38)	059880	0000
	IF(NSSTYP.EQ.1) UROCK=U	059890	0000
	IF(NSSTYP.EQ.2) USOIL=U	059900	0000
	IUSR=UROCK	059910	0000
	IUSS=USOIL	059920	0000
		059930	0000
		059940	0000

(Continued)

C	-----	059950	0000
	IF(NSSTYP.EQ.1) GO TO 110	059960	0000
	GAMMA=B(N,18)	059970	0000
	PERM=ABS(B(N,23))	059980	0000
	IF(NSSTYP.EQ.3) GO TO 110	059990	0000
C	SOFT GROUND SHAFT	060000	0000
	AIRPR=B(N,27)	060010	0000
	IFLOWL=B(N,42)	060020	0000
	STABNO=B(N,24)	060030	0000
	MSTAB=B(N,25)	060040	0000
	IF(MSTAB.EQ.0) STABIL=TNONE	060050	0000
	IF(MSTAB.EQ.1) STABIL=AIRPRS	060060	0000
	IF(MSTAB.EQ.2) STABIL=DEWATR	060070	0000
	IF(MSTAB.EQ.3) STABIL=GRDINJ	060080	0000
C	-----	060090	0000
C	CHECK IF SEGMENT IN SAME SHAFT AS PREVIOUS SEGMENT	060100	0000
110	IF(IPS.EQ.NSHAFT) GO TO 160	060110	0000
C	CONVERT STATIONING OF SHAFT TO INTEGER VALUES	060120	0000
	NPBS=SHAFT(NSHAFT,2)	060130	0000
	NPBS=SHAFT(NSHAFT,3)	060140	0000
	STA=CNP(NPBS,1)	060150	0000
	ISTA=STA/100.	060160	0000
	ISTA2=STA-ISTA*100	060170	0000
	ITENS=ISTA2/10.	060180	0000
	IMUNS=ISTA2-ITENS*10	060190	0000
	IMUNS=IABS(IMUNS)	060200	0000
	BFS=SHAFT(NSHAFT,7)	060210	0000
C	-----	060220	0000
C	CHECK FOR PORTAL	060230	0000
	IF(NPORT.EQ.0) GO TO 112	060240	0000
	WRITE(LO,2200) NSHAFT,ISTA,ITENS,IMUNS,IELNPB,IADS	060250	0000
	GO TO 200	060260	0000
C	-----	060270	0000
C	CHECK FOR DUMMY SHAFT	060280	0000
112	ISHAPS=SHAFT(NSHAFT,16)	060290	0000
	IF(ISHAPS.GT.0) GO TO 115	060300	0000
	WRITE(LO,2100) NSHAFT,ISTA,ITENS,IMUNS,IELNPB,IADS	060310	0000
	GO TO 200	060320	0000
C	-----	060330	0000
C	CALCULATE CONSTRUCTION TIME FOR THE SHAFT (CTS)	060340	0000
115	NSEGS=SHAFT(NSHAFT,4)	060350	0000
	ICTS=0	060360	0000
	MEXP=0	060370	0000
	SETUSH=0.0	060380	0000
	SETUPM=0.0	060390	0000
	DO 120 I=1,NSEGS	060400	0000
	NN=N+I-1	060410	0000
	CTSS=B(NN,40)	060420	0000
	MEX=B(NN,7)	060430	0000
	NSSTYP=B(NN,15)	060440	0000
C	CHECK FOR SHAFT NOT CONSTRUCTED IN CUT AND COVER	060450	0000
	IF(NSSTYP.NE.3) CALL SETUP(MEX,MEXP,SETUSH,SETUPM,SETUPR,ITYPE)	060460	0000
120	ICTS=ICTS+CTSS	060470	0000
	ICTS=ICTS+14.*SETUSH+28.*SETUPM	060480	0000
C	-----	060490	0000
130	WRITE(LO,2222)	060500	0000
	NLINES=N(LINES+1	060510	0000
	NSSTYP=B(N,15)	060520	0000

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AD-A107 890

ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/13
TUNNEL COST-ESTIMATING METHODS.(U)

OCT 81 R D BENNETT

UNCLASSIFIED

WES/TR/8L-81-10

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COSTUN Listing (Continued)

	HOURS=SHAFT(NSHAFT,17)	060530	0000
	DAYS=SHAFT(NSHAFT,18)	060540	0000
	IF(NSSTYP.EQ.3) GO TO 150	060550	0000
	WRITE(LO,2001) NSHAFT,NSSEG,ISTA,ITENS,IHUNS,IELNPB,LSEGL,BFS,BE,	060560	0000
	BOB,AR,ARSULT,TL,IUSS,IUSR,IADS,ICTSS,ICTS,IPRML,HOURS,DAYS	060570	0000
	IF(NSSTYP.EQ.1) GO TO 200	060580	0000
C	-----	060590	0000
C	SOFT GROUND SHAFT	060600	0000
	IF(MSTAB.NE.1) GO TO 140	060610	0000
C	COMPRESSED AIR USED	060620	0000
	WRITE(LO,2003) STABNO,STABIL,AIRPR,IFLOWL,GAMMA,PERM	060630	0000
	NLINES=NLINES+1	060640	0000
	GO TO 200	060650	0000
C	NO COMPRESSED AIR	060660	0000
140	WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM	060670	0000
	NLINES=NLINES+1	060680	0000
	GO TO 200	060690	0000
C	-----	060700	0000
C	CUT AND COVER	060710	0000
150	WRITE(LO,2004) NSHAFT,NSSEG,ISTA,ITENS,IHUNS,IELNPB,LSEGL,BFS,TL,	060720	0000
	IADS,HOURS,DAYS	060730	0000
	WRITE(LO,2005) GAMMA,PERM	060740	0000
	NLINES=NLINES+1	060750	0000
	GO TO 200	060760	0000
C	-----	060770	0000
C	THIS SEGMENT IN SAME SHAFT AS PREVIOUS SEGMENT	060780	0000
160	WRITE(LO,2150)	060790	0000
	NLINES=NLINES+1	060800	0000
	IF(NSSTYP.EQ.3) GO TO 170	060810	0000
	WRITE(LO,2011) NSSEG,IELNPB,LSEGL,BFS,BE,BOB,AR,ARSULT,TL,IUSS,	060820	0000
	IUSR,ICTSS	060830	0000
	IF(NSSTYP.EQ.1) GO TO 200	060840	0000
C	-----	060850	0000
C	SOFT GROUND SHAFT	060860	0000
	IF(MSTAB.NE.1) GO TO 165	060870	0000
C	COMPRESSED AIR USED	060880	0000
	WRITE(LO,2003) STABNO,STABIL,AIRPR,IFLOWL,GAMMA,PERM	060890	0000
	NLINES=NLINES+1	060900	0000
	GO TO 200	060910	0000
C	NO COMPRESSED AIR	060920	0000
165	WRITE(LO,2002) STABNO,STABIL,IFLOWL,GAMMA,PERM	060930	0000
	NLINES=NLINES+1	060940	0000
	GO TO 200	060950	0000
C	-----	060960	0000
C	CUT AND COVER	060970	0000
170	WRITE(LO,2012) NSSEG,IELNPB,LSEGL,BFS,TL	060980	0000
	WRITE(LO,2005) GAMMA,PERM	060990	0000
	NLINES=NLINES+1	061000	0000
200	IPS=NSHAFT	061010	0000
	WRITE(LO,2222)	061020	0000
C	-----	061030	0000
300	IF(IERROR.EQ.0) RETURN	061040	0000
C	FATAL ERRORS DETECTED WHICH MAY MAKE COST CALCULATIONS	061050	0000
C	MEANINGLESS. TERMINATE RUN AND GO TO NEXT SYSTEM DATA DECK	061060	0000
	WRITE(LO,1022)	061070	0000
	CALL NEXSET(LO,LI)	061080	0000
	RETURN	061090	0000
C	-----	061100	0000

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COSTUN Listing (Continued)

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C
C *****
1020 FORMAT(/,35H FATAL ERROR, HAUL SLOPE IN SEGMENT,15,9H IN REACH,
1 15,42H EXCEEDS 5 PERCENT --TOO STEEP FOR A TRAIN)
1021 FORMAT(/, FATAL ERROR, EXCAVATED DIMENSION IN SEGMENT,15, IN
1REACH,15, IS TOO SMALL FOR A TRUCK,USE TRAIN OR CONVEYOR')
1022 FORMAT(/,1X,100(1H),/,10X, EXECUTION HALTED AFTER SUBROUTINE
1 CALCS DUE TO ERRORS ,/,1X,100(1H))
1023 FORMAT(/, FATAL ERROR, SLOPE OF SEGMENT,15, IN REACH,15,
1 EXCEEDS 26 PERCENT --TOO STEEP FOR MUCK TRANSPORT METHODS CON
SIDERED')
1025 FORMAT(/, FATAL ERROR, ALL TRUCK MUCK TRANSPORT IS SPECIFIED IN
1 SEGMENT,15, IN REACH,15, IN WHICH COMPRESSED AIR IS USED')
1030 FORMAT(/,*** REMINDER *** USE OF COMPRESSED AIR IN SEGMENT,
115, IN REACH,15, REQUIRES USE OF CONVEYOR-TRUCK TRANSPORT MET
HOD RATHER,20X, THAN INPUT METHOD')
2000 FORMAT(1H1,42(1H), C A L C U L A T E D S H A F T D A T A ,
146(1H), SHAFT SEG STATION ELEV AT LENGTH *SHAFT DIMENSIONS*
2ADUANCE RATES** LINING *EXCAV VOLUME* SIZE OF CONSTRUCTION RML-
3 HOURS DAYS/12X, ALONG BOTTOM (FT) FINISH EXCAV EXCAV AVER
4AGE UNIFORM THICK SOIL ROCK DISPOSAL TIME (DAYS) MAX PER
5 PER/12X, TUNNEL OF SEG (FT) (FT) W/O.B. USED
6 (IN) (CY/FT)(CY/FT) AREA SEG SHAFT (CY/ DAY WEEK
7/12X, ALIGN, 36X, (FT/DAY) (FT/DAY), 24X, (ACRES), 16X, (HR))
2001 FORMAT(1X,14,15,16,1H+,211,17,18,F7.2,2F6.2,2F8.1,F9.2,217,218,
1216,2F6.1)
2002 FORMAT(21X,F5.1,2X,A6,6X,I9,1X,F11.1,E9.2)
2003 FORMAT(21X,F5.1,2X,A6,F6.1,I9,1X,F11.1,E9.2)
2004 FORMAT(1X,14,15,16,1H+,211,17,18,F7.2,28X,F9.2,14X,I8,20X,2F6.1)
2005 FORMAT(55X,F6.1,E9.2)
2010 FORMAT( 33(2H--,2H )/21X, ***STABILIZATION*** DEWATERING *SOIL
1 PROPERTIES*/21X, NUMBER METHOD AIRPR (GPM/WELL) UNIT WT PER
2M/35X, (PSI), 16X, (PCF) (CM/SEC) )
2011 FORMAT(SX,15,8X,218,F7.2,2F6.2,2F8.1,F9.2,217,8X,I8)
2012 FORMAT(SX,15,8X,218,F7.2,28X,F9.2)
2100 FORMAT(1X)
2100 FORMAT(1X,131(1H-)/1X,I4,5X,I6,1H+,211,17,22X, THIS SHAFT IS A
1 DUMMY, 22X, I8)
2200 FORMAT(1X,131(1H-)/1X,I4,5X,I6,1H+,211,17,22X, THIS SHAFT IS A
1 PORTAL, 21X, I8)
2222 FORMAT(1X,131(1H-))
3000 FORMAT(1H1,41(1H), C A L C U L A T E D T U N N E L D A T A ,
1 45(1H), REACH SEG STATION SLOPE *TUNNEL DIMENSIONS* *ADUAN
2CE RATES** LINING *EXCAV VOLUME* PUMP PUMP CONSTRUCTION RML-
3 HOURS DAYS/12X, AT LEFT LENGTH FINISH EXCAV EXCAV AVERAGE UNIF
4ORM THICK SOIL ROCK FLOW HEIGHT TIME (DAYS) MAX PER P
5ER/12X, OF SEG (FT) (FT) (FT) W/O.B. USED (I
6N) (CY/FT)(CY/FT) RATE (FT) SEG REACH (CY/ DAY WEEK/40X
7 (FT) (FT/DAY) (FT/DAY), 25X, (GPM), 22X, (HR))
3001 FORMAT(1X,14,15,16,1H+,211,16,2F7.2,F6.2,F8.1,F9.1,F9.2,217,I8,I7,
1316,2F6.1)
3002 FORMAT(11X,I5,1H+,211,F7.1,2X,A6,F6.1,I9,1X,F11.1,E9.2)
3004 FORMAT(1X,14,15,16,1H+,211,16,20X,F8.1,F9.1,9X,217,8X,I7,216,6X,
12F6.1)
3005 FORMAT(21X,F5.1,2X,A6,6X,I9,1X,F11.1,E9.2,F8.1,F8.2,F6.2,2F7.1,
1F8.0,T114, F8.0,T122, )
3010 FORMAT( 33(2H--,2H )/12X, AIRLOCK ***STABILIZATION*** DEWATER
1ING *SOIL PROPERTIES* CONCRETE *CUT AND COVER SEGMENT PROPERTIES*

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061110 0000
061120 0000
061130 0000
061140 0000
061150 0000
061160 0000
061170 0000
061180 0000
061190 0000
061200 0000
061210 0000
061220 0000
061230 0000
061240 0000
061250 0000
061260 0000
061270 0000
061280 0000
061290 0000
061300 0000
061310 0000
061320 0000
061330 0000
061340 0000
061350 0000
061360 0000
061370 0000
061380 0000
061390 0000
061400 0000
061410 0000
061420 0000
061430 0000
061440 0000
061450 0000
061460 0000
061470 0000
061480 0000
061490 0000
061500 0000
061510 0000
061520 0000
061530 0000
061540 0000
061550 0000
061560 0000
061570 0000
061580 0000
061590 0000
061600 0000
061610 0000
061620 0000
061630 0000
061640 0000
061650 0000
061660 0000
061670 0000
061680 0000

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COSTUN Listing (Continued)

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      2 REACH//12X, STATION NUMBER METHOD AIRPR (GPM/FEET) UNIT WT 061690 0000
      3 PERM BOX BASE SIDE SUPPORT LENGTH BACKFL OPEN//12X, 061700 0000
      4 '80 TUN//17X, (PSI) SUMP(GPM/FT) (PCF) (CM/SEC) VOLUME WIDTH 061710 0000
      5 SLOPE SLURRY DECKED VOLUME LENGTH//72X, (CY/FT) (FT) U 061720 0000
      6 ALL SOLDIER (CY/FT) (FT)/// 061730 0000
3011 FORMAT(5X, I5, I6, 1H+, 2I1, I6, 2F7.2, F6.2, F8.1, F9.1, F9.2, 2I7, I8, I7, I6) 061740 0000
3014 FORMAT(5X, I5, I6, 1H+, 2I1, I6, 20X, F8.1, F9.1, 9X, 2I7, 8X, I7, I6) 061750 0000
3015 FORMAT(21X, F6.1, 2X, A6, 6X, I6, 1X, F11.1, E9.2, F8.1, F8.2, F6.2, 2F7.1, 061760 0000
      1F8.0, T114, /) 061770 0000
      ***** 061780 0000
C 061790 0000
C 061800 0000
      RETURN 061805
      END 061810 0000
      SUBROUTINE SETUP(MEX, MEXP, SETUSH, SETUPM, SETUPR, ITYPE) 061820 0000
C ----- 061830 0000
C THIS SUBROUTINE COMPUTES THE NUMBER OF SETUP FOR SHIELD, MOLE, 061840 0000
C AND RIPPER EXCAVATION 061850 0000
C ----- 061860 0000
C IF (ITYPE.EQ.2) GO TO 500 061870 0000
C TUNNEL 061880 0000
C IF (MEX.LE.1.OR.MEX.GE.)1//~E10 600 061890 0000
C IF (MEX.LT.3) GO TO 100 061900 0000
C SHIELD SETUP 061910 0000
C IF (SETUSH.GE.1., AND. (MEXP.LT.3.OR.MEXP.GE.6)) SETUSH=SETUSH+.25 061920 0000
C IF (SETUSH.LT.1.) SETUSH=1. 061930 0000
C 100 IF (MEX.GT.3) GO TO 400 061940 0000
C ----- 061950 0000
C MOLE SETUP 061960 0000
C IF (SETUPM.GE.1.) GO TO 150 061970 0000
C FIRST MOLE SETUP 061980 0000
C SETUPM=1. 061990 0000
C GO TO 600 062000 0000
C 150 IF (MEXP.EQ.2.OR.MEXP.EQ.3) GO TO 200 062010 0000
C RESETUP 062020 0000
C SETUPM=SETUPM+.25 062030 0000
C GO TO 600 062040 0000
C CHANGE CUTTER 062050 0000
C 200 IF (MEXP.NE.MEX) SETUPM=SETUPM+.125 062060 0000
C GO TO 600 062070 0000
C RIPPER SETUP 062080 0000
C 400 IF (MEX.EQ.4) GO TO 600 062090 0000
C RESETUP 062100 0000
C IF (MEXP.NE.5.AND.SETUPR.GE.1.) SETUPR=SETUPR+.25 062110 0000
C IF (SETUPR.LT.1.) SETUPR=1. 062120 0000
C GO TO 600 062130 0000
C ----- 062140 0000
C SHAFT 062150 0000
C 500 IF (MEX.LT.2) GO TO 600 062160 0000
C SHIELD SETUP 062170 0000
C IF (MEX.GE.3.AND.SETUSH.LT.1.) SETUSH=1. 062180 0000
C IF (MEX.EQ.4) GO TO 600 062190 0000
C IF (SETUPM.LT.1.) GO TO 550 062200 0000
C CHANGE CUTTER 062210 0000
C IF (MEX.EQ.2.AND.MEXP.EQ.3) SETUPM=SETUPM+.125 062220 0000
C GO TO 600 062230 0000
C FIRST SETUP 062240 0000
C 550 SETUPM=1. 062250 0000

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COSTTU (Continued)

600	NEXP=NEX	062263	0000
	RETURN	062270	0000
	END	062280	0000
	SUBROUTINE COSTTU(A,CNP,SHAFT,TRDATA,CUMSL,NTSMAX,NPMAX,NSMAX,	062290	0000
	INTRMAX,NSSMAX)		062295
C	COSTTU COLLECTS ALL OF THE TUNNEL COSTS AND OUTPUTS THEM	062300	0000
C	-----	062310	0000
	COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE	062330	0000
	COMMON/G/ TUNLC,TUNEC,TUNMC,TUNTC	062340	0000
	DIMENSION IL(12),IE(12),IM(12),CF(3)	062350	0000
	DIMENSION A(NTSMAX,68), CNP(NPMAX,2),SHAFT(NSMAX,23),	062360	0000
1	TRDATA(INTRMAX,23),CUMSL(NPMAX)	062370	0000
C	-----	062380	0000
	INTEGER SLOPF,SECPF,SMCPF,TLC,TEC,TMC	062390	0000
	INTEGER TCES,TCE,TCML,TCMT,TCMH,TCMD,TCTS,TCL,TCFW,	062400	0000
1	TCG,TCP,TCAC,TSCPF, TSC	062410	0000
	INTEGER RCL,RCE,RCM,RCI	062420	0000
	INTEGER TUNLC,TUNEC,TUNMC,TUNTC	062430	0000
C	-----	062440	0000
C	CALCULATE TUNNEL COSTS A REACH AT A TIME	062450	0000
C	ITYPE=1	062460	0000
	TUNLC=0	062470	0000
	TUNEC=0	062480	0000
	TUNMC=0	062490	0000
	TUNTC=0	062500	0000
C	-----	062510	0000
	DO 950 NREACH=1,INTRMAX	062520	0000
	IF (TRDATA(NREACH,1).LT.-10.E29) GO TO 950	062530	0000
	NSHAFT=TRDATA(NREACH,1)	062540	0000
	BF=TRDATA(NREACH,2)	062550	0000
	ISHAPE=TRDATA(NREACH,3)	062560	0000
	MTM=TRDATA(NREACH,4)	062570	0000
	NRSEG1=TRDATA(NREACH,5)	062580	0000
	NSEGS=TRDATA(NREACH,6)	062590	0000
	RMLMAX=TRDATA(NREACH,7)	062600	0000
	HOURS =TRDATA(NREACH,8)	062610	0000
	DAYS =TRDATA(NREACH,9)	062620	0000
	SETUSH=TRDATA(NREACH,10)	062630	0000
	SETUPM=TRDATA(NREACH,11)	062640	0000
	SETUPR=TRDATA(NREACH,12)	062650	0000
	DTCA =TRDATA(NREACH,14)	062660	0000
	DTC =TRDATA(NREACH,15)	062670	0000
	IF (ISHAPE.EQ.1) SFA=0.785	062680	0000
	IF (ISHAPE.EQ.1) SFP=3.14	062690	0000
	IF (ISHAPE.EQ.2) SFA=0.893	062700	0000
	IF (ISHAPE.EQ.2) SFP=3.57	062710	0000
	IF (ISHAPE.EQ.3) SFA=0.425	062720	0000
	IF (ISHAPE.EQ.3) SFP=2.66	062730	0000
C	-----	062740	0000
	NBOX =TRDATA(NREACH,10)	062750	0000
	BFBUDT =TRDATA(NREACH,11)	062760	0000
	BFBHT =TRDATA(NREACH,12)	062770	0000
	IBOX2 =TRDATA(NREACH,13)	062780	0000
	TIMEDW=TRDATA(NREACH,14)	062790	0000
	OPEN =TRDATA(NREACH,16)	062800	0000
		062810	0000

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COSTING Listing (Continued)

	UDS =TRDATA(NREACH,21)	062828	0000
	UBACEX=TRDATA(NREACH,22)	062830	0000
	UBACDS=TRDATA(NREACH,23)	062840	0000
C	NPBS=SHAFT(NSHAFT,3)	062850	0000
	DDS=SHAFT(NSHAFT,6)	062860	0000
	CDS=SHAFT(NSHAFT,6)	062870	0000
	HH=SHAFT(NSHAFT,8)	062880	0000
	NSEGSA=IABS(NSEGS)	062890	0000
C	-----	062910	0000
C	DETERMINE NUMBER OF SHIFTS IN A WORK DAY	062920	0000
	SHIFTS=1.	062930	0000
	IF(HOURS.GE.12.) SHIFTS=2.	062940	0000
	IF(HOURS.GE.21.) SHIFTS=3.	062950	0000
C	CALCULATE COST FACTORS FOR LENGTH OF WORK WEEK	062960	0000
	IF(HOURS/SHIFTS.LE.8.) CFLWK=(6.08+0.192*(DAYS-4.))*2	062970	0000
	1 +0.384*SHIFTS)*SHIFTS/HOURS	062980	0000
	IF(HOURS/SHIFTS.GT.8.) CFLWK=(0.76+0.024*(DAYS-4.))*2	062990	0000
	1 +0.048*SHIFTS)*(1.5-4.*SHIFTS/HOURS)	063000	0000
	CFLWK=(3.75+30./HOURS)/DAYS	063010	0000
C	-----	063020	0000
	ALOCK=1.0	063030	0000
	CLIND=0.	063040	0000
	UCMCP=0.	063050	0000
	IF(ISHAPE.EQ.0.OR.DTCA.EQ.0.) GO TO 5	063060	0000
C	CALCULATE COST OF INSTALLATION OF CONVEYOR IN FREE AIR FOR	063070	0000
C	CONVEYOR+TRUCK TRANSPORT, AND COST OF COMPRESSED AIR PIPING	063080	0000
	CALL CUINFA(A,CNP,CUMSL,HH,NPBS,NSEGS,RMLMAX,DTCA,NRSEG1,	063090	0000
	1 CLIND,UCMCP,NTSMAX,NPMAX)	063100	0000
C	-----	063110	0000
C	CALCULATE NUMBER OF AIR LOCK LOCATIONS AND LENGTH OF LOCK	063120	0000
	CALL LOCKLT(A,NSEGS,RMLMAX,MTM,ALOCK,ALOCKL,NTSMAX,NRSEG1)	063130	0000
C	-----	063140	0000
	5 RL=0.0	063150	0000
	DO 10 IJ=1,NSEGSA	063160	0000
	IF(NSEGS.GT.0) I=NRSEG1+IJ-1	063170	0000
	IF(NSEGS.LT.0) I=NRSEG1-IJ+1	063180	0000
	TSEGL=A(I,45)	063190	0000
	10 RL=RL+TSEGL	063200	0000
C	-----	063210	0000
	RCL=0.	063220	0000
	RCE=0.	063230	0000
	RCM=0.	063240	0000
	RCT=0.	063250	0000
	NLINES=60	063260	0000
C	-----	063270	0000
C	CALCULATE TUNNEL COSTS FOR EACH SEGMENT	063280	0000
C	-----	063290	0000
	DO 900 IS=1,NSEGSA	063300	0000
	I=SEQUENCE NUMBER OF TUNNEL SEGMENT	063310	0000
	I=NRSEG1+IS-1	063320	0000
	NPS=A(I,17)	063330	0000
	IF(NSEGS.GT.0) GO TO 110	063340	0000
	I=NRSEG1-IS+1	063350	0000
	NPS=A(I,18)	063360	0000
	110 NPL =A(I,2)	063370	0000
	NPR =A(I,3)	063380	0000
		063390	0000

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COSTUN Listing (Continued)

	ELNPL =CNP(NPL,2)	063403 0000
	ELNPR =CNP(NPR,2)	063410 0000
	ELAUG =0.5*(ELNPL+ELNPR)	063420 0000
	RS=A(I,5)	063430 0000
	ROD=A(I,6)	063440 0000
	MEX=A(I,7)	063450 0000
	AR=A(I,8)	063460 0000
	GI=A(I,9)	063470 0000
C	THE VARIABLE FOR LINING TYPE IS CALLED L1(ONE)N1(ONE)NG IN THIS	063480 0000
C	---	063490 0000
C	SUBROUTINE TO AVOID COMPUTER CONFUSION WITH THE CALL TO SUB LINING	063500 0000
C	WHICH COMPUTES LINING COSTS	063510 0000
	LINING=A(I,10)	063520 0000
	TL =A(I,11)	063530 0000
	TSEG =A(I,11)	063540 0000
	NOFORM=A(I,13)	063550 0000
	ELWATR=A(I,14)	063560 0000
	LINWT =A(I,15)	063570 0000
	NTSTYP=A(I,16)	063580 0000
	IF(NTSTYP.EQ.1) GO TO 115	063590 0000
	NPLS =A(I,17)	063600 0000
	NPRS =A(I,18)	063610 0000
C	CALCULATE AVERAGE SURFACE ELEVATION	063620 0000
	ELNPLS=CNP(NPLS,2)	063630 0000
	ELNPRS=CNP(NPRS,2)	063640 0000
	ELSURF=0.5*(ELNPLS+ELNPRS)	063650 0000
C	DEPTH OF TUNNEL	063660 0000
	DTUN=ELSURF-ELAUG	063670 0000
C	CALCULATE DEPTH OF ROCK SURFACE	063680 0000
	ELROCK=A(I,27)	063690 0000
	DROCK=ELSURF-ELROCK	063700 0000
C		063710 0000
115	ELBOTM=ELAUG-0.5*BE	063720 0000
C	IF(ISHAPE.EQ.3) ELBOTM=ELAUG-0.25*BE	063730 0000
		063740 0000
	D10 =A(I,19)	063750 0000
	PHI =A(I,20)	063760 0000
	PERM=A(I,25)	063770 0000
	ISUPPT=A(I,26)	063780 0000
	IBRACE=A(I,28)	063790 0000
	IDECK=A(I,29)	063800 0000
	STABNO=A(I,30)	063810 0000
	MSTAB=A(I,31)	063820 0000
	AIRPR=A(I,33)	063830 0000
	CAUT =A(I,35)	063840 0000
	QT =A(I,37)	063850 0000
	Q =A(I,38)	063860 0000
	BE =A(I,39)	063870 0000
	BE40 =A(I,40)	063880 0000
	BE60 =A(I,41)	063890 0000

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COSTUM LISTING (Cont Inued)

	DOB =A(I,42)	063900 0000
	DOB40 =A(I,43)	063910 0000
	DOB60 =A(I,44)	063920 0000
C	TSEQL =A(I,45)	063930 0000
	DM =A(I,46)	063940 0000
	MSLOPE=A(I,47)	063950 0000
	RML =A(I,48)	063960 0000
	U =A(I,51)	063970 0000
C	TOTBOX=A(I,43)	063980 0000
	DIRNCH=A(I,52)	063990 0000
	SIDESL=A(I,53)	064000 0000
	VBOX =A(I,54)	064010 0000
	UL =A(I,55)	064020 0000
	FORMAR=A(I,56)	064030 0000
C	PH =A(I,57)	064040 0000
	PIPL =A(I,58)	064050 0000
	FLOW =A(I,59)	064060 0000
	GIR =A(I,60)	064070 0000
	FLOWL =A(I,61)	064080 0000
C	WEB =A(I,62)	064090 0000
	TPLATE=A(I,62)	064100 0000
	UTUALE=A(I,63)	064110 0000
	UTSTRT=A(I,64)	064120 0000
	UTANCH=A(I,65)	064130 0000
	UTSP =A(I,66)	064140 0000
	UTSPD =A(I,67)	064150 0000
C	WELLS =A(I,68)	064160 0000
	SPDLT =A(I,38)	064170 0000
	DSLURY=A(I,38)	064180 0000
	PSOIL =A(I,63)	064190 0000
	PUATER=A(I,64)	064200 0000
	PTOTAL=A(I,65)	064210 0000
	IWATER=A(I,23)	064220 0000
C	-----	
C	LABOR COST FACTOR IN COMPRESSED AIR	064230 0000
	CFLCA=AIRPRX2/400.+1.5	064240 0000
	IF(NTSTYP.NE.2.OR.AIRPR.LE.0.) CFLCA=1.	064250 0000
C	COST FACTOR FOR TRAVEL TIME TO THE FACE	064260 0000
	Y=0.3*SHIFTS*(0.76+0.024*(DAYS-4.)*2+0.048*SHIFTS)	064270 0000
	IF(HOURS/SHIFTS.LT.8.) Y=Y*5.*(HOURS/SHIFTS+0.2*DM-8.)/DM	064280 0000
	IF(Y.LT.0.) Y=0.	064290 0000
	IF(NTSTYP.EQ.3) Y=0.	064300 0000
C	CLES=0.	064310 0000
	CEES=0.	064320 0000
	CHES=0.	064330 0000
	CLAC=0.	064340 0000
	CEAC=0.	064350 0000
	CHAC=0.	064360 0000
	IF(NTSTYP.EQ.3) GO TO 750	064370 0000
	IF(MSTAB.NE.1) GO TO 750	064380 0000
	IF(IS.NE.1) GO TO 700	064390 0000
	DLOCK=0.	064400 0000
		064410 0000
		064420 0000
		064430 0000
		064440 0000
		064450 0000
		064460 0000
		064470 0000

(Cont Inued)

	NPLOCK=ABS(A(I,36))	064480	0000
	DTHLOCK=HH	064490	0000
	PUMPLT=DTHLOCK+DM*5280.	064500	0000
	GO TO 750	064510	0000
C	CALCULATE LENGTH OF PIPING FOR COMPRESSED AIR	064520	0000
700	IF(ABS(A(I,36)).EQ.NPLOCK) GO TO 720	064530	0000
	NPLOCK=ABS(A(I,36))	064540	0000
	DTHLOCK=CNP(NPS,2)-CNP(NPLOCK,2)	064550	0000
	DLOCK=ABS(CUMSL(NPLOCK)-CUMSL(NPS))	064560	0000
720	PUMPLT=DM*5280.-DLOCK+DTHLOCK	064570	0000
	IF(DLOCK.GT.0.001) HSFA=(CNP(NPS,2)-CNP(NPLOCK,2))/DLOCK	064580	0000
	HSCA=(CNP(NPLOCK,2)-ELAUG)/(DM*5280.-DLOCK)	064590	0000
C	-----	064600	0000
C	CALCULATE SETUP COST FOR TUNNEL SEGMENT I	064610	0000
750	CALL CSETUP(A,B,NSEGS,NRSEG1,BE,HH,ITYPE,I,SETUSH,SETUPM,SETUPR,	064620	0000
	1 CLES,CEES,CMES,CFLWUK,CFEWUK,NTSTYP,DSES,DMES,DRES,NTSMAX,NSSMAX)	064630	0000
C	-----	064640	0000
C	CALCULATE COST OF EXCAVATION IN TUNNEL SEGMENT I	064650	0000
	CALL COEX(CLE,CEE,CME,ITYPE,MEX,AR,BE,RS,ISHAPE,SFA,SFP,	064660	0000
	1 PSOIL,STABNO,DTRNCH,DROCK,SIDESL,UBOX,USOIL,URCK,PHI,	064670	0000
	2 DCENT,HOURS,Y,DM,MSTAB,CFLCA,CFLWUK,CFEWUK,NTSTYP)	064680	0000
C	-----	064690	0000
C	CALCULATE COST OF MUCK LOADING IN TUNNEL SEGMENT I	064700	0000
	CALL CMUKLD(CML,CML,CMML,ITYPE,MEX,AR,DM,U,Y,RML,RMLMAX,	064710	0000
	1 MSTAB,CFLCA,CFLWUK,CFEWUK,HOURS)	064720	0000
C	-----	064730	0000
C	CALCULATE MUCK TRANSPORTATION AND HOISTING COSTS FOR	064740	0000
C	TUNNEL SEGMENT I	064750	0000
	CALL CNTAH(CLMT,CEMT,CMMT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR,	064760	0000
	1HSFA,U,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPE,RL,UCLT,UCET,Y,UCLMH,	064770	0000
	2HSCA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,UBACEX,UBACDS,UBOX,	064780	0000
	3 USOIL,URCK,TOTBOX,CFLWUK,CFEWUK,CFLCA,DDS,NTSTYP,DTRNCH,DROCK)	064790	0000
C	-----	064800	0000
C	CALCULATE MUCK DISPOSAL COST FOR TUNNEL SEGMENT I	064810	0000
	CALL CMUKDP(CLMD,CEMD,CMMD,AR,U,CDS,DDS,UDS,NTSTYP,HOURS,	064820	0000
	1 CFLWUK,CFEWUK,ITYPE)	064830	0000
C	-----	064840	0000
C	CALCULATE COST OF TUNNEL SUPPORTS FOR TUNNEL SEGMENT I	064850	0000
	IF(LINING.EQ.4.AND.NTSTYP.EQ.1)GO TO 1900		
	IF(LINING.NE.4.OR.NTSTYP.NE.1)GO TO 2000		
1900	CALL ROCK(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60,		
	1ITYPE,Y,NTSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTOTAL,		
	2BOB,LINWT,MSTAB,CFLCA,HOURS,CFLWUK,CFEWUK,SFA,LINING,DM,		
	3CLL,CCL,CML,CLFU,CEFU,CMFU)		
	GO TO 2500		
2000	CONTINUE		
	CALL CTSUP(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60,ITYPE,	064860	0000
	1 Y,DM,NTSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTOTAL,BOB,LINWT,	064870	0000
	2 MSTAB,CFLCA,HOURS,CFLWUK,CFEWUK,DSLURY,DTRNCH,IDECK,DROCK,	064880	0000
	3 UTSTRY,UTWALE,SPDLT,UTSPD,UTSP,UTANCH,TOTBOX,IBRACE,SFA)	064890	0000
C	-----	064900	0000
C	CALCULATE COST OF LINING AND FORMWORK IN TUNNEL SEGMENT I	064910	0000
	CALL LINING1(CLL,CCL,CML,CLFU,CEFU,CMFU,ITYPE,LINING,RQD,MEX,	064920	0000
	1WEB,TL,BOB,BOB40,BF,Y,DM,BOB60,ISHAPE,BE,UCLT,UCET,MTM,	064930	0000
	2UCLMH,UCENH,SFA,NOFORM,AR,NTSTYP,PSOIL,PWATER,UL,SFP,	064940	0000
	3FORMAR,HOURS,CFLCA,CFLWUK,CFEWUK)	064950	0000
2500	CONTINUE		
C	-----	064960	0000

(Continued)

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C	CALCULATE GROUTING COSTS FOR TUNNEL SEGMENT I	064970	0000
	CALL CGROUT(CLG,SEG,CHG,ITYPE,GT,ISHAPE,BE,AR,RS,NTSTYP,MSTAB,	064980	0000
1	DTUN,HH,HOURS,CFLWUK,CFEWUK,SSEGL,PERM,SFP,DTG,TIMEG)	064990	0000
C	-----	065000	0000
C	CALCULATE COST OF PUMPING FOR TUNNEL SEGMENT I	065010	0000
	CALL CPUMP(CLP,CEP,CHP,NTSTYP,FLOW,PH,PIPL,AR,ITYPE,	065020	0000
1	ELSURF,ELBOTH,DAYS,LINING,PUMPTM,MEX,DTRNCH,DROCK,FLOWL,	065030	0000
2	WELLS,RL,TIMEDW,ISUPPT,ELWATR,ELNPS,IWATER,CFLWUK,CFEWUK)	065040	0000
C	-----	065050	0000
C	CALCULATE COST OF AIR CONDITIONING AND COMPRESSED AIR FOR TUNNEL	065060	0000
C	SEGMENT I	065070	0000
	CALL CAIRC(CLAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NTSTYP,MSTAB,ITYPE,	065080	0000
1	AIRPR,SFA,ISHAPE,HH,CAUT,ALOCK,DTG,DTCA,PUMPLT,DM,	065090	0000
2	ALOCKL,UCHCP,CFLWUK,CFEWUK,DAYS,Y,PERM)	065100	0000
C	-----	065110	0000
C		065120	0000
C		065130	0000
C		065140	0000
	IF(LIST(6).EQ.1) GO TO 810	065150	0000
	IF(NLINES+10.LT.60) GO TO 810	065160	0000
	WRITE(LO,1000)	065170	0000
	NLINES=6	065180	0000
C	-----	065190	0000
C	CALCULATE COST FACTORS	065200	0000
810	POP=(1.+0.01*OM)*X(1.+0.01*PM)	065210	0000
C	CF(1),CF(2) AND CF(3) ARE COMPOSITE COST FACTORS FOR L, E, AND M.	065220	0000
	CFL=SHAFT(NSHAFT,12)	065230	0000
	CFE=SHAFT(NSHAFT,13)	065240	0000
	CFM=SHAFT(NSHAFT,14)	065250	0000
	RCF=SHAFT(NSHAFT,15)	065260	0000
	CF(1)=POP*CFL*RCF	065270	0000
	CF(2)=POP*CFE*RCF	065280	0000
	CF(3)=POP*CFM*RCF	065290	0000
C	-----	065300	0000
C	MULTIPLY BY COMPOSITE COST FACTORS AND THEN OBTAIN SEGMENT	065310	0000
C	COSTS PER FOOT TO THE NEAREST DOLLAR	065320	0000
	IL(1)=CLES*CF(1)+.5	065330	0000
	IE(1)=CEES*CF(2)+.5	065340	0000
	IM(1)=CMES*CF(3)+.5	065350	0000
	IL(2)=CLE *CF(1)+.5	065360	0000
	IE(2)=CEE *CF(2)+.5	065370	0000
	IM(2)=CME *CF(3)+.5	065380	0000
	IL(3)=CLML*CF(1)+.5	065390	0000
	IE(3)=CENL*CF(2)+.5	065400	0000
	IM(3)=CMNL*CF(3)+.5	065410	0000
	IL(4)=CLMT*CF(1)+.5	065420	0000
	IE(4)=CEMT*CF(2)+.5	065430	0000
	IM(4)=CMMT*CF(3)+.5	065440	0000
	IL(5)=CLMH*CF(1)+.5	065450	0000
	IE(5)=CEMH*CF(2)+.5	065460	0000
	IM(5)=CMMH*CF(3)+.5	065470	0000
	IL(6)=CLMD*CF(1)+.5	065480	0000
	IE(6)=CEMD*CF(2)+.5	065490	0000
	IM(6)=CMND*CF(3)+.5	065500	0000
	IL(7)=CLTS*CF(1)+.5	065510	0000
	IE(7)=CETS*CF(2)+.5	065520	0000
	IM(7)=CMTS*CF(3)+.5	065530	0000
	IL(8)=CLL *CF(1)+.5	065540	0000

(Continued)

COSTUN Listing (Continued)

IE(8)=CEL XCF(8)+.5	065550	0000
IM(8)=CHL XCF(3)+.5	065560	0000
IL(9)=CLFWXCF(1)+.5	065570	0000
IE(9)=CEFWXCF(8)+.5	065580	0000
IM(9)=CMFWXCF(3)+.5	065590	0000
IL(10)=CLG XCF(1)+.5	065600	0000
IE(10)=CEG XCF(8)+.5	065610	0000
IM(10)=CMG XCF(3)+.5	065620	0000
IL(11)=CLP XCF(1)+.5	065630	0000
IE(11)=CEP XCF(2)+.5	065640	0000
IM(11)=CMP XCF(3)+.5	065650	0000
IL(12)=CLACXCF(1)+.5	065660	0000
IE(12)=CEACXCF(2)+.5	065670	0000
IM(12)=CMACXCF(3)+.5	065680	0000
C-----	065690	0000
C CALCULATE SEGMENT COST/FOOT FOR LABOR, EQUIPMENT AND MATERIALS	065700	0000
SLCPF=0	065710	0000
SECPF=0	065720	0000
SMCPF=0	065730	0000
DO 815 LL=1,12	065740	0000
SLCPF=SLCPF+IL(LL)	065750	0000
SECPF=SECPF+IE(LL)	065760	0000
815 SMCPF=SMCPF+IM(LL)	065770	0000
TSCPF=SLCPF+SECPF+SMCPF	065780	0000
C-----	065790	0000
C CALCULATE TOTAL SEGMENT COST/FOOT FOR EACH COST COMPONENT	065800	0000
TCES = IE(1)+IM(1)+IL(1)	065810	0000
TCE = IE(2)+IM(2)+IL(2)	065820	0000
TCML = IE(3)+IM(3)+IL(3)	065830	0000
TCMT = IE(4)+IM(4)+IL(4)	065840	0000
TCMH = IE(5)+IM(5)+IL(5)	065850	0000
TCMD = IE(6)+IM(6)+IL(6)	065860	0000
TCTS = IE(7)+IM(7)+IL(7)	065870	0000
TCL = IE(8)+IM(8)+IL(8)	065880	0000
TCFW = IE(9)+IM(9)+IL(9)	065890	0000
TCG = IE(10)+IM(10)+IL(10)	065900	0000
TCP = IE(11)+IM(11)+IL(11)	065910	0000
TCAC = IE(12)+IM(12)+IL(12)	065920	0000
C-----	065930	0000
C CALCULATE TOTAL SEGMENT COSTS IN THOUSANDS OF DOLLARS	065940	0000
TLC = SLCPF*ITSEGL/1000.	065950	0000
TEC = SECPF*ITSEGL/1000.	065960	0000
TMC = SMCPF*ITSEGL/1000.	065970	0000
TSC = TLC+TEC+TMC	065980	0000
C-----	065990	0000
C IF(LIST(6).EQ.1) GO TO 840	066000	0000
C WRITE OUT THE SEGMENT COSTS FOR LABOR, EQUIP, MAT, AND TOTAL	066010	0000
ITSEGL=ITSEGL	066020	0000
NTSEG=A(I,1)	066030	0000
WRITE(LO,1001) NREACH,NTSEG,(IL(JJJ),JJJ=1,12),SLCPF,TLC	066040	0000
WRITE(LO,1002) (IE(JJJ),JJJ=1,12),SECPF,TEC	066050	0000
WRITE(LO,1003) (IM(JJJ),JJJ=1,12),SMCPF,TMC	066060	0000
WRITE(LO,1004) TCES,TCE,TCML,TCMT,TCMH,TCMD,TCTS,TCL,TCFW,	066070	0000
TCG,TCP,TCAC,TSCPF,ITSEGL, TSC	066080	0000
C	066090	0000
NLINES=NLINES+5	066100	0000
C	066110	0000
C ACCUMULATE TUNNEL SEGMENT COSTS INTO COST OF REACH	066120	0000

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840 RCL=RCL+TLC
RCE=RCE+TEC
RCM=RCM+TMC
RCT=RCL+RCE+RCM
C END OF COSTS ON A SEGMENT BASIS
900 CONTINUE
C -----
C LIST OUT REACH COSTS
850 IF(LIST(6).EQ.1) GO TO 860
WRITE(LO,1007) SHAFT(NSHAFT,12),RCL, SHAFT(NSHAFT,15),
1 SHAFT(NSHAFT,13),RCE, SHAFT(NSHAFT,14),RCM,CFLWUK,RCT,CFEWUK
NLINE=NLINE+7
C -----
C ACCUMULATE COSTS OF ALL REACHES
860 TUNLC=TUNLC+RCL
TUNEC=TUNEC+RCE
TUNMC=TUNMC+RCM
TUNTC=TUNTC+RCT
C
TRDATA(NREACH,17)=RCL
TRDATA(NREACH,18)=RCE
TRDATA(NREACH,19)=RCM
TRDATA(NREACH,20)=RCT
C END OF COSTS ON A REACH BASIS
950 CONTINUE
RETURN
C -----
1000 FORMAT(1H1,47(1H),27H T U N N E L C O S T S ,46(1H)//
1120H REACH SEG ***** COST IN DOLLARS PER FOOT OF TUNNE
2L ***** SEG SEGMENT SEGMENT /
3120H NO NO EXC EXC MUCK MUCK MUCK MUCK SUP- LIN- /
4LIN GROUT PUMP- AIR- COST LENGTH COST /
5120H SETUP LOAD TRAN HOIST DISP PORTS ING F
60RM ING COND ($/FT) (FEET) ($1000)
7 /,1X,119(1H-)
1001 FORMAT(/1X,13,15,2H L,13I6,8X,112)
1002 FORMAT(9X, 2H E,13I6,8X,112)
1003 FORMAT(9X, 2H M,13I6,8X,112)
1004 FORMAT(9X, 2H T,13I6,18,112)
1007 FORMAT(1X,119(1H-)//,9X,14HREGIONAL COST,6X,10HCOST INDEX,10X,
1 10H -- LABOR ,F5.2,5X,31HTOTAL REACH LABOR COST .....19/
2 9X,9HFACTOR ,F5.2,26X,10HEQUIPMENT,F5.2,5X,
3 31HTOTAL REACH EQUIPMENT COST .....19/
4 49X,10H MATERIALS ,F5.2,5X,31HTOTAL REACH MATERIALS COST .....19/
5 43X,16HLABOR WORK WEEK ,F5.2,5X,
6 31HTOTAL REACH COST .....19/
7 43X,16HEQUIP WORK WEEK ,F5.2)
C -----
C END
C SUBROUTINE COSTSF(B,CNP,SHAFT,TRDATA,NSSMAX,NPMAX,NSMAX,NTRMAX,
INTSMAX)
C -----

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(Continued)

C	-----	066680	0000
C	COST6F COLLECTS ALL OF THE SHAFT COSTS AND OUTPUTS THEM	066690	0000
C	-----	066700	0000
C	DIMENSION IL(11),IE(11),IM(11),CF(3)	066710	0000
	COMMON /A/ LO,LI,PM,OM,LIST(40),TITLE(160),STABEG,ITYPE	066720	0000
	COMMON/Q/ TUNLC,TUNEC,TUNMC,TUNTC	066740	0000
	DIMENSION B(NSSMAX,43),CNP(NPMAX,2),SHAFT(NSMAX,23),TRDATA(NTRMAX,	066750	0000
1	23)	066760	0000
	-----	066770	0000
C	INTEGER SLOPF,SECPF,SMCPF,TLC,TEC,TMC	066780	0000
	INTEGER TCES,TCE,TCML,TCMH,TCMD,TCTS,TCL,TCFW,TCP,TCAC,	066790	0000
1	TCG,TSCPF,TSC	066800	0000
	INTEGER SCL,SCE,SCM,SCT	066810	0000
	INTEGER TUNLC,TUNEC,TUNMC,TUNTC	066820	0000
	INTEGER SFTTLC,SFTTEC,SFTTMC,SFTTC	066830	0000
	INTEGER TLABOR,TEQUIP,TMATER,TCOST	066840	0000
	INTEGER RCL,RCE,RCM,RCT	066850	0000
	-----	066860	0000
C	CALCULATE COSTS A SHAFT AT A TIME	066870	0000
C	Y=0.0	066880	0000
	ITYPE=2	066890	0000
C		066900	0000
C		066910	0000
	SFTTLC=0	066920	0000
	SFTTEC=0	066930	0000
	SFTTMC=0	066940	0000
	SFTTC=0	066950	0000
	DO 950 NSHAFT=1,NSMAX	066960	0000
	IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 950	066970	0000
	BF=SHAFT(NSHAFT,7)	066980	0000
	NSSEG1=SHAFT(NSHAFT,1)	066990	0000
	NSEGS=SHAFT(NSHAFT,4)	067000	0000
	RMLMAX=SHAFT(NSHAFT,10)	067010	0000
	DDS=SHAFT(NSHAFT,5)	067020	0000
	CDS=SHAFT(NSHAFT,6)	067030	0000
C		067040	0000
	ISHAPS=SHAFT(NSHAFT,16)	067050	0000
	HOURS =SHAFT(NSHAFT,17)	067060	0000
	DAYS =SHAFT(NSHAFT,18)	067070	0000
	NPORT =SHAFT(NSHAFT,23)	067080	0000
	SFA=0.785	067090	0000
	SFP=3.14	067100	0000
	IF(ISHAPS.EQ.2) SFA=1.0	067110	0000
	IF(ISHAPS.EQ.2) SFP=4.0	067120	0000
C	DETERMINE NUMBER OF SHIFTS PER WORK DAY	067130	0000
	SHIFTS=1.	067140	0000
	IF(HOURS.GE.12.) SHIFTS=2.	067150	0000
	IF(HOURS.GE.21.) SHIFTS=3.	067160	0000
C	CALCULATE COST FACTOR FOR LENGTH OF WORK WEEK	067170	0000
	IF(HOURS/SHIFTS.LE.8.) CFLWUK=(6.08+0.192*(DAYS-4.))*12	067180	0000
1	+0.384*SHIFTS)*SHIFTS/HOURS	067190	0000
	IF(HOURS/SHIFTS.GT.8.) CFLWUK=(0.76+0.024*(DAYS-4.))*12	067200	0000
1	+0.048*SHIFTS)*(1.5-4.*SHIFTS/HOURS)	067210	0000
	CFEWUK=(3.75+30./HOURS)/DAYS	067220	0000
C	-----	067230	0000
C	CALCULATE LENGTH OF SEGMENTS REQUIRE GROUTING AND PUMPING	067240	0000
	DTG=0.	067250	0000
		067260	0000

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CONSTRUCTION (Continued)

DTP=0.	067270	0000
DO 10 NN=1,NSEGS	067280	0000
II=NSSEG1+NN-1	067290	0000
MSTAB=B(II,25)	067300	0000
SSEGL=B(II,35)	067310	0000
MH=B(II,36)	067320	0000
FLOUL=B(II,42)	067330	0000
IF(FLOUL.GT.0.) DTP=DTP+SSEGL	067340	0000
IF(MSTAB.NE.3.OR.MH.GT.200.) GO TO 10	067350	0000
DTG=DTG+SSEGL	067360	0000
TIMEG=0.33+(MH+0.5*SSEGL)/20.	067370	0000
10 CONTINUE	067380	0000
C-----	067390	0000
SCL=0.	067400	0000
SCE=0.	067410	0000
SCM=0.	067420	0000
SCT=0.	067430	0000
NLINES=60	067440	0000
C	067450	0000
CC CALCULATE SHAFT COSTS FOR EACH SEGMENT	067460	0000
CC	067470	0000
CC	067480	0000
DO 900 ISS=1,NSEGS	067490	0000
C I=SEQUENCE NUMBER OF SHAFT SEGMENT	067500	0000
I=NSSEG1+ISS-1	067510	0000
C CHECK FOR A PORTAL OR A DUMMY SHAFT	067520	0000
IF(NPORT.EQ.0.AND.ISHAPS.NE.0) GO TO 67	067530	0000
C THIS SHAFT IS A PORTAL OR A DUMMY SHAFT	067540	0000
IF(LIST(7).EQ.0) WRITE(10,3005) NSHAFT	067550	0000
GO TO 860	067560	0000
67 NPB=B(I,4)	067570	0000
ELNPB=CNP(NPB,2)	067580	0000
RS=B(I,5)	067590	0000
RQD=B(I,6)	067600	0000
MEX=B(I,7)	067610	0000
AR=B(I,8)	067620	0000
GI=B(I,9)	067630	0000
C THE VARIABLE FOR LINING TYPE IS CALLED L1(ONE)N1(ONE)NG IN THIS	067640	0000
CC	067650	0000
CC SUBROUTINE TO AVOID COMPUTER CONFUSION WITH THE CALL TO SUB LINING	067660	0000
C WHICH COMPUTES LINING COSTS	067670	0000
LINING=B(I,10)	067680	0000
TL=B(I,11)	067690	0000
TSEG=B(I,11)	067700	0000
NOFORM=B(I,12)	067710	0000
ELWATR=B(I,13)	067720	0000
LINUT=B(I,14)	067730	0000
NSSTYP=B(I,15)	067740	0000
D10=B(I,16)	067750	0000
C	067760	0000
PHI=B(I,19)	067770	0000
ELIMP=B(I,20)	067780	0000
IUATER=B(I,21)	067790	0000
ISUPPT=B(I,22)	067800	0000
PERH=B(I,23)	067810	0000
STABNO=B(I,24)	067820	0000
MSTAB=B(I,25)	067830	0000
AIRPR=B(I,27)	067840	0000

(Continued)

COSTPN Listing (Continued)

C	BE =B(I,20)	067850	0000
	BE40 =B(I,30)	067860	0000
	BE60 =B(I,31)	067870	0000
	BOB =B(I,32)	067880	0000
	BOB40 =B(I,33)	067890	0000
	BOB60 =B(I,34)	067900	0000
C	SSQL =B(I,35)	067910	0000
	HH =B(I,36)	067920	0000
	PH=B(I,36)	067930	0000
	RML =B(I,37)	067940	0000
	U =B(I,38)	067950	0000
	WEB =B(I,41)	067960	0000
	TPLATE=B(I,41)	067970	0000
	FLOUL =B(I,42)	067980	0000
C	PSOIL =B(I,30)	067990	0000
	PTOTAL=B(I,31)	068000	0000
	PWATER=B(I,43)	068010	0000
C	LABOR COST FACTOR IN COMPRESSED AIR	068020	0000
	CFLCA=AIRPRX2/400.+1.5	068030	0000
	IF(NSSTYP.NE.2.OR.AIRPR.LE.0.) CFLCA=1.	068040	0000
C		068050	0000
C		068060	0000
C		068070	0000
C		068080	0000
C		068090	0000
C	-----	068100	0000
	CALCULATE SETUP COST FOR SHAFT SEGMENT I	068110	0000
	CALL CSETUP(A,B,NSEGS,NSSEG1,BE,HH,ITYPE,I,SETUSH,SETUPM,SETUPR,	068120	0000
	1 CLES,CEES,CMES,CFLWUK,CFEWUK,NSSTYP,DSES,DMES,DRES,NTSMAX,NSSMAX)	068130	0000
C	-----	068140	0000
C	CALCULATE PUMPING TIME	068150	0000
	PUMPTM=0.	068160	0000
	IF(FLOUL.LE.0.) GO TO 700	068170	0000
	PUMPTM=(5.+14.*SETUSH+28.*SETUPM)/DTP+7./DAYS/AR	068180	0000
	AL=2.*HOURS	068190	0000
	IF(LINING.EQ.1) PUMPTM=PUMPTM+(30.+SHAFT(NSHAFT,8)/AL*7./DAYS)	068200	0000
	1 /DTP	068210	0000
	IF(LINING.EQ.2) PUMPTM=PUMPTM+30./DTP	068220	0000
700	CONTINUE	068230	0000
C	-----	068240	0000
C	CALCULATE COST OF EXCAVATION IN SHAFT SEGMENT I	068250	0000
	CALL COEX(CLE,CEE,CME,ITYPE,MEX,AR,BE,RS,ISHAPS,SFA,SFP,	068260	0000
	1 PSOIL,STABNO,DTRNCH,DROCK,SIDESL,UBOX,USOIL,UROCK,PHI,	068270	0000
	2 DCENT,HOURS,Y,DM,MSTAB,CFLCA,CFLWUK,CFEWUK,NSSTYP)	068280	0000
C	-----	068290	0000
C	CALCULATE COST OF MUCK LOADING IN SHAFT SEGMENT I	068300	0000
	CALL CMUKLD(CML,CENL,CMLL,ITYPE,MEX,AR,DM,U,V,RML,RMLMAX,	068310	0000
	1 NSTAB,CFLCA,CFLWUK,CFEWUK,HOURS)	068320	0000
C	-----	068330	0000
C	CALCULATE MUCK HOISTING COSTS FOR SHAFT SEGMENT I	068340	0000
	CALL CNTAH(CLMT,CENT,CMMT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR,	068350	0000
	1HSFA,U,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPS,RL,UCLT,UCET,V,UCLMH,	068360	0000
	2HSCA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,UBACEX,UBACDS,UBOX,	068370	0000
	3 USOIL,UROCK,TOTBOX,CFLWUK,CFEWUK,CFLCA,DDS,NSSTYP,DTRNCH,DROCK)	068380	0000
C	-----	068390	0000
C	CALCULATE MUCK DISPOSAL COST FOR SHAFT SEGMENT I	068400	0000
	CALL CMUKDP(CLMD,CEND,CMD,AR,U,CDS,DDS,UDS,NSSTYP,HOURS,	068410	0000
	1 CFLWUK,CFEWUK,ITYPE)	068420	0000

(Continued)

COSTEN Listing (Continued)

C	-----	068430	0000
C	CALCULATE COST OF SHAFT SUPPORTS FOR SHAFT SEGMENT I	068440	0000
	CALL CTSUP(CLT5,CET5,CMT5,RQD,MEX,ISHAPS,BE,AR,RS,BE40,BE60,ITYPE,	068450	0000
1	Y,DM,NSSTYP,BF,ISUPPT,TPLATE,TSEG,P50IL,UES,POTAL,BOB,LINUT,	068460	0000
2	MSTAB,CFLCA,HOURS,CFLWUK,CFEWUK,DSLURY,DTANCH,IDECK,DROCK,	068470	0000
3	UTSTRT,UTWALE,SPDLT,UTSPD,UTSP,UTANCH,TOTBOX,IBRACE,SFA)	068480	0000
C	-----	068490	0000
C	CALCULATE COST OF LINING AND FORMWORK IN SHAFT SEGMENT I	068500	0000
	CALL LINING(CLL,CCL,CML,CFLW,CFEU,CMFU,ITYPE,LINING,RQD,MEX,	068510	0000
	1UES,TL,BOB,BOB40,BF,Y,DM,BOB60,ISHAPS,BE,UCLT,UCET,MTM,	068520	0000
	2UCLHW,UCERH,SFA,NOFORM,AR,NSSTYP,P50IL,PWATER,UL,SFP,	068530	0000
	3FORMAR,HOURS,CFLCA,CFLWUK,CFEWUK)	068540	0000
C	-----	068550	0000
C	CALCULATE GROUTING COSTS FOR SHAFT SEGMENT I	068560	0000
	CALL CGROUT(CLG,CEG,CMG,ITYPE,GI,ISHAPS,BE,AR,RS,NSSTYP,MSTAB,	068570	0000
1	DTUN,HH,HOURS,CFLWUK,CFEWUK,SSEGL,PERM,SFP,DTG,TIMEG)	068580	0000
C	-----	068590	0000
C	CALCULATE COST OF PUMPING FOR SHAFT SEGMENT I	068600	0000
	CALL CPUMP(CLP,CEP,CMP,NSSTYP,FLOW,PH,PIPL,AR,ITYPE,	068610	0000
1	ELSURF,ELBOTM,DAYS,LINING,PUMPTM,MEX,DTANCH,DROCK,FLOWL,	068620	0000
2	WELLS,AL,TIMEDW,ISUPPT,ELWATR,ELNFB,IWATER,CFLWUK,CFEWUK)	068630	0000
C	-----	068640	0000
C	CALCULATE COST OF AIR CONDITIONING AND COMPRESSED AIR	068650	0000
	FOR SHAFT SEGMENT I	068660	0000
	CALL CAIRC(CLAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NSSTYP,MSTAB,ITYPE,	068670	0000
1	AIRPR, SFA,ISHAPS,HH,CAUT,ALOCK,DTG,DTCA,PUMPLT,DM,	068680	0000
2	ALOCKL,UCMCP,CFLWUK,CFEWUK,DAYS,Y,PERM)	068690	0000
C	-----	068700	0000
C		068710	0000
C		068720	0000
C		068730	0000
	IF(LIST(7).EQ.1) GO TO 810	068740	0000
	IF(NLINES+11.LT.60) GO TO 810	068750	0000
	WRITE(LO,2000)	068760	0000
	NLINES=6	068770	0000
C	-----	068780	0000
C	CALCULATE COST FACTORS	068790	0000
810	POP=(1.+0.01XOM)*X(1.+0.01XPM)	068800	0000
C	CF(1),CF(2) AND CF(3) ARE COMPOSITE COST FACTORS FOR L, E, AND M	068810	0000
	CFL=SHAFT(NSHAFT,12)	068820	0000
	CFE=SHAFT(NSHAFT,13)	068830	0000
	CFM=SHAFT(NSHAFT,14)	068840	0000
	RCF=SHAFT(NSHAFT,15)	068850	0000
	CF(1)=POP*CFL*RCF	068860	0000
	CF(2)=POP*CFE*RCF	068870	0000
	CF(3)=POP*CFM*RCF	068880	0000
C	-----	068890	0000
C	MULTIPLY BY COMPOSITE COST FACTORS AND THEN OBTAIN SEGMENT	068900	0000
	COSTS PER FOOT TO THE NEAREST DOLLAR	068910	0000
	IL(1)=CLES*CF(1)+.5	068920	0000
	IE(1)=CEES*CF(2)+.5	068930	0000
	IM(1)=CMES*CF(3)+.5	068940	0000
	IL(2)=CLE*CF(1)+.5	068950	0000
	IE(2)=CEE*CF(2)+.5	068960	0000
	IM(2)=CME*CF(3)+.5	068970	0000
	IL(3)=CLML*CF(1)+.5	068980	0000
	IE(3)=CEML*CF(2)+.5	068990	0000
	IM(3)=CMML*CF(3)+.5	069000	0000

(Continued)

COSTUM Listing (Continued)

IL(4)=CLMH*CF(1)+.5	069010	0000
IE(4)=CEMH*CF(2)+.5	069020	0000
IM(4)=CMH*CF(3)+.5	069030	0000
IL(5)=CLMD*CF(1)+.5	069040	0000
IE(5)=CEMD*CF(2)+.5	069050	0000
IM(5)=CMD*CF(3)+.5	069060	0000
IL(6)=CLTS*CF(1)+.5	069070	0000
IE(6)=CETS*CF(2)+.5	069080	0000
IM(6)=CMTS*CF(3)+.5	069090	0000
IL(7)=CLL *CF(1)+.5	069100	0000
IE(7)=CEL *CF(2)+.5	069110	0000
IM(7)=CML *CF(3)+.5	069120	0000
IL(8)=CLFW*CF(1)+.5	069130	0000
IE(8)=CEFW*CF(2)+.5	069140	0000
IM(8)=CMFW*CF(3)+.5	069150	0000
IL(9)=CLG *CF(1)+.5	069160	0000
IE(9)=CEG *CF(2)+.5	069170	0000
IM(9)=CMG *CF(3)+.5	069180	0000
IL(10)=CLP *CF(1)+.5	069190	0000
IE(10)=CEP *CF(2)+.5	069200	0000
IM(10)=CMP *CF(3)+.5	069210	0000
IL(11)=CLAC*CF(1)+.5	069220	0000
IE(11)=CEAC*CF(2)+.5	069230	0000
IM(11)=CMAC*CF(3)+.5	069240	0000
C-----	069250	0000
C CALCULATE SEGMENT COST/FOOT FOR LABOR, EQUIPMENT AND MATERIALS	069260	0000
SLCPF=0	069270	0000
SECPF=0	069280	0000
SMCPF=0	069290	0000
DO 815 LL=1,11	069300	0000
SLCPF=SLCPF+IL(LL)	069310	0000
SECPF=SECPF+IE(LL)	069320	0000
815 SMCPF=SMCPF+IM(LL)	069330	0000
TSCPF=SLCPF+SECPF+SMCPF	069340	0000
C-----	069350	0000
C CALCULATE TOTAL SEGMENT COST/FOOT FOR EACH COST COMPONENT	069360	0000
TCES = IE(1)+IM(1)+IL(1)	069370	0000
TCE = IE(2)+IM(2)+IL(2)	069380	0000
TCML = IE(3)+IM(3)+IL(3)	069390	0000
TCMH = IE(4)+IM(4)+IL(4)	069400	0000
TCMD = IE(5)+IM(5)+IL(5)	069410	0000
TCTS = IE(6)+IM(6)+IL(6)	069420	0000
TCL = IE(7)+IM(7)+IL(7)	069430	0000
TCFW = IE(8)+IM(8)+IL(8)	069440	0000
TCG = IE(9)+IM(9)+IL(9)	069450	0000
TCP = IE(10)+IM(10)+IL(10)	069460	0000
TCAC = IE(11)+IM(11)+IL(11)	069470	0000
C-----	069480	0000
C CALCULATE TOTAL SEGMENT COSTS IN THOUSANDS OF DOLLARS	069490	0000
TLC = SLCPF*SSSEGL/1000.	069500	0000
TEC = SECPF*SSSEGL/1000.	069510	0000
TMC = SMCPF*SSSEGL/1000.	069520	0000
TSC = TLC+TEC+TMC	069530	0000
C-----	069540	0000
C IF(LIST(7).EQ.1) GO TO 840	069550	0000
C WRITE OUT THE SEGMENT COSTS FOR LABOR, EQUIP, MAT, AND TOTAL	069560	0000
ISSEGL=SSSEGL	069570	0000
NSSEG=B(1,2)	069580	0000

(Continued)

COSTEN Listing (Continued)

	WRITE(LO,2001) NSHAFT,NSSEQ,(IL(JJJ),JJJ=1,11),SLCPF,TLC	069500 0000
	WRITE(LO,2002) (IE(JJJ),JJJ=1,11),SECPF,TEC	069500 0000
	WRITE(LO,2003) (IM(JJJ),JJJ=1,11),SMCPF,TMC	069510 0000
	WRITE(LO,2004) TCES,TCE,TCML,TCMH,TCMD,TCTS,TCL,TCFU,	069520 0000
	1 TCG,TCP,TCAC,TSCPF,ISSEGL,TSC	069530 0000
C	NLINES=NLINES+5	069540 0000
C		069550 0000
C	ACCUMULATE SHAFT SEGMENT COSTS INTO COST OF SHAFT	069560 0000
840	SCL=SCL+TLC	069570 0000
	SCE=SCE+TEC	069580 0000
	SCM=SCM+TMC	069590 0000
	SCT=SCL+SCE+SCM	069600 0000
C	END OF COSTS ON A SEGMENT BASIS	069710 0000
900	CONTINUE	069720 0000
C		069730 0000
C	LIST OUT TOTAL COST OF SHAFT	069740 0000
850	IF(LIST(7).EQ.1) GO TO 860	069750 0000
	WRITE(LO,1004) SHAFT(NSHAFT,12),SCL,SHAFT(NSHAFT,15),	069760 0000
	1 SHAFT(NSHAFT,13),SCE,SHAFT(NSHAFT,14),SCM,CFLWUK,SCT,CFEWUK	069770 0000
	NLINES=NLINES+7	069780 0000
C		069790 0000
C		069800 0000
C	ACCUMULATE COSTS OF ALL SHAFTS	069810 0000
860	SFTTLC=SFTTLC+SCL	069820 0000
	SFTTEC=SFTTEC+SCE	069830 0000
	SFTTMC=SFTTMC+SCM	069840 0000
	SFTTC=SFTTLC+SFTTEC+SFTTMC	069850 0000
C		069860 0000
	SHAFT(NSHAFT,19)=SCL	069870 0000
	SHAFT(NSHAFT,20)=SCE	069880 0000
	SHAFT(NSHAFT,21)=SCM	069890 0000
	SHAFT(NSHAFT,22)=SCT	069900 0000
C	END OF COSTS ON A SHAFT BASIS	069910 0000
950	CONTINUE	069920 0000
C		069930 0000
C	PRINT REACH COST SUMMARIES	069940 0000
	IF(LIST(8).EQ.1) GO TO 965	069950 0000
	WRITE(LO,1500)	069960 0000
	NLINES=5	069970 0000
	DO 960 NREACH=1,NTRMAX	069980 0000
	IF(TRDATA(NREACH,1).LT.-10.E29) GO TO 960	069990 0000
	NSHAFT=TRDATA(NREACH,1)	070000 0000
	RCL=TRDATA(NREACH,17)	070010 0000
	RCE=TRDATA(NREACH,18)	070020 0000
	RCH=TRDATA(NREACH,19)	070030 0000
	RCT=TRDATA(NREACH,20)	070040 0000
	WRITE(LO,1501) NREACH,NSHAFT,SHAFT(NSHAFT,15),(SHAFT(NSHAFT,JJ),	070050 0000
	1 JJ=12,1),RCL,RCE,RCH,RCT	070060 0000
	NLINES=NLINES+2	070070 0000
	IF(NLINES.LT.58) GO TO 960	070080 0000
	WRITE(LO,1500)	070090 0000
	NLINES=5	070100 0000
960	CONTINUE	070110 0000
965	CONTINUE	070120 0000
C		070130 0000
C	PRINT SHAFT COST SUMMARIES	070140 0000
	IF(LIST(9).EQ.1) GO TO 975	070150 0000
		070160 0000

(Continued)

COSTUN Listing (Continued)

WRITE(LO,1000)	070170	0000
NLINES=5	070180	0000
DO 970 NSHAFT=1,NSMAX	070190	0000
IF(SHAFT(NSHAFT,1).LT.-10.E29) GO TO 970	070200	0000
SCL=SHAFT(NSHAFT,9)	070210	0000
SCE=SHAFT(NSHAFT,20)	070220	0000
SCM=SHAFT(NSHAFT,21)	070230	0000
SCT=SHAFT(NSHAFT,22)	070240	0000
WRITE(LO,1601) NSHAFT,SHAFT(NSHAFT,15),(SHAFT(NSHAFT,JJ),JJ=12,14)	070250	0000
1 SCL,SCE,SCM,SCT	070260	0000
NLINES=NLINES+2	070270	0000
IF(NLINES.LT.58) GO TO 970	070280	0000
WRITE(LO,1600)	070290	0000
NLINES=5	070300	0000
970 CONTINUE	070310	0000
075 CONTINUE	070320	0000
C -----	070330	0000
C TOTAL PROJECT CONSTRUCTION COSTS	070340	0000
TLABOR=TUNLC+SFTTLC	070350	0000
TEQUIP=TUNEC+SFTTEC	070360	0000
TMATER=TUNMC+SFTTMC	070370	0000
TCOST=TUNTC+SFTTC	070380	0000
C -----	070390	0000
C PRINT PROJECT SUMMARY SHEET	070400	0000
WRITE(LO,2) TITLE	070410	0000
WRITE(LO,1005) PM,TUNLC,OM,TUNEC,TUNMC,TUNTC	070420	0000
WRITE(LO,1006) SFTTLC,SFTTEC,SFTTMC,SFTTC	070430	0000
WRITE(LO,1007) TLABOR,TEQUIP,TMATER,TCOST	070440	0000
C -----	070450	0000
C RETURN	070460	0000
C -----	070470	0000
C	070480	0000
2 FORMAT(1H1,10(/),50X,70(1H),/,50X,1H,68X,1H,	070490	0000
110(/,50X,1H,2X,16A4,2X,1H),	070500	0000
3 //,50X,1H,68X,1H,/,50X,70(1H),///)	070510	0000
1004 FORMAT(1X,119(1H-),/,7X,14HREGIONAL COST,6X,10HCOST INDEX,10X	070520	0000
110H -- LABOR ,F5.2, 5X,25HSHAFT LABOR COSTI9/	070530	0000
2 7X,9HFACTOR ,F5.2,26X,10HEQUIPMENT ,F5.2,5X,	070540	0000
3 25HSHAFT EQUIPMENT COSTI9/	070550	0000
4 47X,10HMATERIALS ,F5.2, 5X,25HSHAFT MATERIALS COSTI9/	070560	0000
5 41X,16HLABOR WORK WEEK ,F5.2,5X,25HSHAFT COSTI9/	070570	0000
6 41X,16HEQUIP WORK WEEK ,F5.2)	070580	0000
1005 FORMAT(50X,17HPROFIT MARGIN ,F5.2,3X,	070590	0000
1 36HTOTAL TUNNEL LABOR COST.....(\$1000),I9/,	070600	0000
2 50X,17HOVERHEAD MARGIN ,F5.2,3X,	070610	0000
3 36HTOTAL TUNNEL EQUIPMENT COST.....I9/,	070620	0000
4 75X,36HTOTAL TUNNEL MATERIAL COST.....I9/,	070630	0000
5 75X,36HTOTAL TUNNEL COST.....I9/)	070640	0000
1006 FORMAT(//,75X,36HTOTAL SHAFT LABOR COST.....I9/	070650	0000
1 75X,36HTOTAL SHAFT EQUIPMENT COST.....I9/	070660	0000
2 75X,36HTOTAL SHAFT MATERIAL COST.....I9/	070670	0000
3 75X,36HTOTAL SHAFT COST.....I9/)	070680	0000
1007 FORMAT(//,75X,35HTOTAL PROJECT LABOR COST.....I10/	070690	0000
1 75X,35HTOTAL PROJECT EQUIPMENT COST.....I10/	070700	0000
2 75X,35HTOTAL PROJECT MATERIAL COST.....I10/	070710	0000
3 75X,35HTOTAL PROJECT COST.....I10)	070720	0000
1500 FORMAT(1H1,1X,34(1H),50H T U N N E L R E A C H C O S T S U M	070730	0000
1M A R Y ,35(1H)// 14X,19HEXIT REGIONAL ,6(1H),	070740	0000

(Continued)

COSTUN Listing (Continued)

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      2 12HCOST INDEXES,6(1H),10X,17(1H),15H COSTS ($1000),16(1H)/,
      3 3X,62HREACH SHAFT COST FACTOR LABOR EQUIP MATL,
      4 16X,41HLABOR EQUIPMENT MATERIAL TOTAL,/,1X,119(1H-)/)
1501 FORMAT(4X,I3,8X,I3,7X,F4.2,2X,3(4X,F4.2),11X,4(3X,I9)/)
1600 FORMAT(1H1,1X,41(1H),37H S H A F T C O S T S U M M A R Y ,
      1 41(1H)/, 23X,10HREGIONAL,6(1H),12HCOST INDEXES,6(1H),
      2 10X,17(1H),15H COSTS ($1000),16(1H)/,3X,5HSHAFT,14X,
      3 33HCOST FACTOR LABOR EQUIP MATL,18X,
      4 41HLABOR EQUIPMENT MATERIAL TOTAL,/,1X,119(1H-)/)
1601 FORMAT(4X,I3,18X,F4.2,2X,3(4X,F4.2),11X,4(3X,I9)/)
2000 FORMAT(1H1,45(1H),23H S H A F T C O S T S U M M A R Y ,
1180H SHAFT SEG ***** COST IN DOLLARS PER FOOT OF SHAFT
***** SEG SEGMENT SEGMENT
3180H NO NO EXC EXC MUCK MUCK MUCK SUP- LIN- LIN GR
40UT PUMP- AIR- COST LENGTH COST
5120H SETUP LOAD MOIST DISP PORTS ING FORM
      6 ING COND ($/FT) (FEET) ($1000)
      7 /,1X,119(1H-)/)
2001 FORMAT(/,1X,I3,I5,2H L,12I6,8X,I10)
2002 FORMAT(9X, 2H E,12I6,8X,I10)
2003 FORMAT(9X, 2H M,12I6,8X,I10)
2004 FORMAT(9X, 2H T,12I6,18,I10)
3005 FORMAT(1H1,6H SHAFT,14, ' IS A PORTAL OR A DUMMY SHAFT ALL CO
1STS ARE ZERO')
C -----
C RETURN
END
SUBROUTINE CUINFA(A,CNP,CUMSL,HH,NPBS,NSEGS,RMLMAX,DTCA,NRSEG1,
1CLIND,UCMCP,NTSMAX,NPMAX)
DIMENSION A(NTSMAX,68), CNP(NPMAX,2),CUMSL(NPMAX)
C -----
C THIS SUBROUTINE COMPUTES THE TOTAL LENGTH OF SEGMENTS WHICH ARE
C EXCAVATED IN FREE AIR BUT NEED CONVEYOR BELT FOR FURTHER
C EXCAVATION IN COMPRESSED AIR. IT ALSO COMPUTES THE COST OF
C COMPRESSED AIR PIPING
C -----
C DTACH=0.
UCMCP=0.
NSEGSA=IABS(NSEGS)
C -----
C DO 100 I=1,NSEGSA
J=NSEGSA-I+1
N=NRSEG1+J-1
IF(NSEGS.LT.0) N=NRSEG1-J+1
MSTAB=A(N,31)
DM=A(N,46)
TSEGL=A(N,45)
C CHECK LAST SEGMENT IN THE REACH AND SET LOCK POSITION
IF(I.EQ.1) NPLOCK=A(N,2)
C CHECK THE POSITION OF AIR LOCK FOR THIS SEGMENT WITH THE POSITION
C FOR THE NEXT SEGMENT IN COMPRESSED AIR
IF(ABS(A(N,36)).EQ.NPLOCK) GO TO 50
C CHECK IF THE SEGMENT IN COMPRESSED AIR
IF(MSTAB.NE.1) GO TO 100
10 NPLOCK=ABS(A(N,36))
DLOCK=ABS(CUMSL(NPLOCK)-CUMSL(NPB5))
C FIND THE SURFACE NODAL POINT OF AIR LOCK

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(Continued)

COSTUN Listing (Continued)

DO 80 K=1,J	071330 0000
IF(NSEGS.LT.0) GO TO 60	071340 0000
NN=NRSEQ1-K-1	071350 0000
NPREND=A(NN,2)	071360 0000
NPS=A(NN,17)	071370 0000
GO TO 70	071380 0000
80 NN=NRSEQ1-K+1	071390 0000
NPREND=A(NN,3)	071400 0000
NPS=A(NN,18)	071410 0000
70 IF(NPLOCK.EQ.NPREND) GO TO 90	071420 0000
80 CONTINUE	071430 0000
C CALCULATE COST OF COMPRESSED AIR PIPING	071440 0000
90 DTHLCK=CNP(NPS,2)-CNP(NPLOCK,2)	071450 0000
PUMPLT=DM*5280.-DLOCK+DTHLCK	071460 0000
CAUT=A(N,35)	071470 0000
UCMCP=UCMCP+(25.+0.0018*CAUT-0.000000015*CAUT**2)*PUMPLT/DCA	071480 0000
GO TO 100	071490 0000
50 IF (MSTAB.NE.1) DTFACN=DTFACN+TSEGL	071500 0000
IF(MSTAB.EQ.1.AND.I.EQ.1) GO TO 10	071510 0000
100 CONTINUE	071520 0000
C COMPUTE THE INSTALLATION COST OF CONVEYOR IN THE FREE AIR SEGMENTS	071530 0000
CLIND=(0.31*SQRT(RMLMAX+40.))+1.38)*DTFACN/DCA	071540 0000
RETURN	071550 0000
END	071560 0000
SUBROUTINE LOCKLT(A,NSEGS,RMLMAX,MTM,ALOCK,ALOCKL,NTSMAX,NRSEQ1)	071570 0000
DIMENSION A(NTSMAX,68)	071580 0000
C-----	071590 0000
C LOCKLT COMPUTES NUMBER OF AIR LOCK LOCATIONS AND LENGTH OF AIR	071600 0000
C LOCK IN A REACH	071610 0000
C-----	071620 0000
ALOCK=1.	071630 0000
ALOCKL=30.	071640 0000
M=0	071650 0000
NSEGSA=IABS(NSEGS)	071660 0000
C-----	071670 0000
C NUMBER OF AIR LOCK LOCATIONS IN REACH	071680 0000
DO 100 II=1,NSEGSA	071690 0000
I=NRSEQ1+(II-1)*NSEGS/NSEGSA	071700 0000
MSTAB=A(I,31)	071710 0000
IF(MSTAB.NE.1) GO TO 100	071720 0000
M=M+1	071730 0000
C FIRST COMPRESSED AIR SEGMENT	071740 0000
IF(M.NE.1) GO TO 10	071750 0000
NPLOCK=A(I,36)	071760 0000
IF(NPLOCK.LT.0) M=-1000000	071770 0000
10 IF(NPLOCK.NE.A(I,36)) ALOCK=ALOCK+1.	071780 0000
C-----	071790 0000
C LENGTH OF AIR LOCK	071800 0000
IF(MTM.NE.3) GO TO 100	071810 0000
AR=A(I,8)	071820 0000
DM=A(I,46)	071830 0000
CARS=(1.+0.7/(DM+2.))*RMLMAX*(0.06+0.12*DM**0.333	071840 0000
+AR*(0.06+0.023*DM-0.12*DM**0.333)/300.)	071850 0000
IF(CARS.LT.1.) CARS=1.	071860 0000
ENGINE=CARS/11.	071870 0000
IF(ENGINE.LT.1.) ENGINE=1.	071880 0000
ALOKLT=17.*(CARS/ENGINE+1.)	071890 0000
IF(ALOCKL.LT.ALOKLT) ALOCKL=ALOKLT	071900 0000

(Continued)

COSTUN Listing (Continued)

100	CONTINUE	071510	0000
C	-----	071520	0000
C	ALOCK = NEGATIVE FOR COOLING PLANT FOR FIRST LOCK MOVED FROM SHAFT	071530	0000
C	TO GROUND SURFACE ABOVE SECOND LOCK POSITION	071540	0000
	IF(M.LT.0) ALOCK=-ALOCK	071550	0000
	RETURN	071560	0000
	END	071570	0000
	SUBROUTINE CSETUP(A,B,NSEGS,NSEG1,BE,HH,ITYPE,I,SETUSH,SETUPM,	071580	0000
	1,SETUPR,CLES,CEES,CHES,CFLWUK,CFEUWK,NSTYP,DSES,DMES,DRES,NTSMAX,	071590	0000
	2,NSSMAX)	071595	
C	-----	072000	0000
C	CSETUP DETERMINES THE AVERAGE COSTS INVOLVED IN SETTING UP THE	072010	0000
C	NECESSARY EQUIPMENT TO EXCAVATE EACH SEGMENT	072020	0000
C	-----	072030	0000
	DIMENSION A(NTSMAX,68),B(NSSMAX,43)	072050	0000
C	-----	072060	0000
	IF(NSTYP.EQ.3) GO TO 500	072070	0000
C	INITIALIZE	072080	0000
	UCLSS=0.	072090	0000
	UCESS=0.	072100	0000
	UCMSS=0.	072110	0000
	UCLMS=0.	072120	0000
	UCEMS=0.	072130	0000
	UCMMS=0.	072140	0000
	UCLRS=0.	072150	0000
	UCERS=0.	072160	0000
	UCMRS=0.	072170	0000
C	-----	072180	0000
	IF(ITYPE.EQ.2) GO TO 200	072190	0000
C	TUNNEL	072200	0000
C	FIRST SEGMENT IN THE REACH	072210	0000
	IF(I.NE.NSEG1) GO TO 150	072220	0000
C	DETERMINE THE TOTAL LENGTH OF SHIELD, MOLE AND RIPPER EXCAVATED	072230	0000
C	SEGMENTS IN A REACH	072240	0000
	DSES=0.0000001	072250	0000
	DMES=0.0000001	072260	0000
	DRES=0.0000001	072270	0000
	NSEGSA=IABS(NSEGS)	072280	0000
	DO 100 NN=1,NSEGSA	072290	0000
	M=NSEG1+(NN-1)*NSEGS/NSEGSA	072300	0000
	MEX=A(M,7)	072310	0000
	TSEGL=A(M,45)	072320	0000
	IF(MEX.LE.1.OR.MEX.GE.6) GO TO 100	072330	0000
C	SHIELD	072340	0000
	IF(MEX.GE.3) DSES=DSES+TSEGL	072350	0000
C	MOLE	072360	0000
	IF(MEX.LE.3) DMES=DMES+TSEGL	072370	0000
C	RIPPER	072380	0000
	IF(MEX.EQ.5) DRES=DRES+TSEGL	072390	0000
100	CONTINUE	072400	0000
150	MEX=A(I,7)	072410	0000
	IF(MEX.LE.1.OR.MEX.GE.6) GO TO 400	072420	0000
C	SHIELD SET UP COSTS	072430	0000
	IF(MEX.LT.3) GO TO 160	072440	0000
	UCLSS=(2000.+3.*HH+45.*BE**2)*SETUSH	072450	0000
	UCESS=(2000.+0.04*BE*HH+21.*BE**2)*SETUSH	072460	0000
	UCMSS=(700.+0.1*HH+2.5*(BE-6.)*BE**2)*SETUSH	072470	0000
C	MOLE SETUP COSTS	072480	0000

(Continued)

COSTUN Listing (Continued)

160	IF(MEX.GT.3) GO TO 170	072400	0000
	UCLMS=(50000.+15.XHH+152.X(BE+12.)XX2)XSETUPM	072500	0000
	UCERS=(25000.+6.XHH+234.X(BE-10.)XX2)XSETUPM	072510	0000
	UCMMS=25.XBEXX2XSETUPM	072520	0000
C	RIPPER SETUP COSTS	072530	0000
170	IF(MEX.LE.5) GO TO 400	072540	0000
	UCLRS=(4000.+HHX(1.+0.05XBE)+6.8XBEXX2)XSETUPR	072550	0000
	UCERS=(1000.+0.7XHH+1.5X(BE+5.)XX2)XSETUPR	072560	0000
	UCMRS=(150.+0.09XHH+0.2XBEXX2)XSETUPR	072570	0000
	GO TO 400	072580	0000
C	-----	072590	0000
C	SHAFT	072600	0000
200	IF(I.LE.NSEG1) GO TO 350	072610	0000
	DSES=0.0000001	072620	0000
	DMES=0.0000001	072630	0000
	DRES=0.0000001	072640	0000
C	DETERMINE THE TOTAL LENGTH OF SHIELD AND MOLE EXCAVATED	072650	0000
C	SEGMENTS IN A SHAFT	072660	0000
	SETUSH=0.	072670	0000
	SETUPM=0.	072680	0000
	DO 300 NN=1,NSEGS	072690	0000
	M=NSEG1+NN-1	072700	0000
	MEX=B(M,7)	072710	0000
	SSEGL=B(M,35)	072720	0000
	IF(MEX-2) 300,220,210	072730	0000
C	SHIELD	072740	0000
210	DSES=DSES+SSEGL	072750	0000
	IF(SETUSH.LT.1.) SETUSH=1.	072760	0000
	IF(MEX.EQ.4) GO TO 300	072770	0000
C	MOLE	072780	0000
220	DMES=DMES+SSEGL	072790	0000
	IF(SETUPM.LT.1.) GO TO 250	072800	0000
	IF(MEX.EQ.2.AND.MEXP.EQ.3) SETUPM=SETUPM+0.125	072810	0000
	GO TO 300	072820	0000
250	SETUPM=1.	072830	0000
300	MEXP=MEX	072840	0000
C	-----	072850	0000
350	MEX=B(I,7)	072860	0000
C	SHIELD SETUP COSTS	072870	0000
	IF(MEX.LT.3) GO TO 360	072880	0000
	UCLSS=(2000.+930.XBE)XSETUSH	072890	0000
	UCESS=(500.+14.X(BE-5.)XX2)XSETUSH	072900	0000
	UCMSS=(300.+X(BE-3.)XX2)XSETUSH	072910	0000
C	MOLE SETUP COSTS	072920	0000
360	IF(.NOT.(MEX.EQ.2.OR.MEX.EQ.3)) GO TO 400	072930	0000
	UCLMS=(130.X(BE+5.)XX2+65000.)XSETUPM	072940	0000
	UCERS=(165.X(BE-10.)XX2+20000.)XSETUPM	072950	0000
	UCMMS=(30.X(BE-10.)XX2+3200.)XSETUPM	072960	0000
C	-----	072970	0000
C	TOTAL SETUP COSTS	072980	0000
400	CLES=(UCLSS/DSES+UCLMS/DMES+UCLRS/DRES)XCFLOWK	072990	0000
	CEES=(UCESS/DSES+UCERS/DMES+UCERS/DRES)XCFLOWK	073000	0000
	CMES=(UCMSS/DSES+UCMMS/DMES+UCMRS/DRES	073010	0000
	RETURN	073020	0000
C	-----	073030	0000
500	CLES=0.	073040	0000
	CEES=0.	073050	0000
	CMES=0.	073060	0000

(Continued)

COSTUN Listing (Continued)

	RETURN	073070	0000
	END	073080	0000
	SUBROUTINE COEX(CLE,CEE,CME,ITYPE,MEX,AR,BE,RS,ISHAPE,SFA,SFP,	073090	0000
	PSOIL,STABNO,DTRNCH,DRCK,SIDSL,UBOX,USOIL,URCK,FHT,	073100	0000
	DCENT,HOURS,V,DM,MSTAB,CFLCA,CFLWUK,CFEWUK,NSTYP)	073110	0000
C	-----	073120	0000
C	COEX CALCULATES EXCAVATION COSTS IN TUNNELS AND SHAFTS	073130	0000
C	-----	073140	0000
C	IF(NSTYP.NE.2) GO TO 110	073150	0000
C	CALCULATE WEIGHT OF SHIELD	073160	0000
	F=1.	073170	0000
	IF(ISHAPE.EQ.3) F=1.56	073180	0000
	IF(ITYPE.EQ.2.AND.ISHAPE.EQ.2) F=2.	073190	0000
	UTSHLD=(0.037*SQRT(81.+F*BE**2)-0.038)*PSOIL*STABNO**2*SFP	073200	0000
C	-----	073210	0000
110	IF(ITYPE.EQ.2) GO TO 100	073220	0000
C	CALCULATE UNIT COST OF TUNNEL EXCAVATION	073230	0000
C	CHECK TUNNEL EXCAVATION METHODS	073240	0000
C	GO TO (120,220,320,420,520,620,620),MEX	073250	0000
C	ROCK TUNNEL	073260	0000
C	CONVENTIONAL EXCAVATION	073270	0000
120	GO TO (121,122,123),ISHAPE	073280	0000
C	SHAPE IS CIRCLE	073290	0000
121	UCL=0.07*(BE+40.)*X2-100.	073300	0000
	UCE=0.046*(BE+15.)*X2	073310	0000
	UCH=SFA*SQRT(RS)*BE**2/2000.+(0.11*(BE+10.)*X2-25.)/AR	073320	0000
	GO TO 124	073330	0000
C	SHAPE IS HORSESHOE	073340	0000
122	UCL=0.08*(BE+40.)*X2-110.	073350	0000
	UCE=0.05*(BE+15.)*X2+4.	073360	0000
	UCH=SFA*SQRT(RS)*BE**2/2000.+(0.12*(BE+10.)*X2-22.)/AR	073370	0000
	GO TO 124	073380	0000
C	SHAPE IS BASKETHANDLE	073390	0000
123	UCL=0.1*(BE**2+60.	073400	0000
	UCE=0.04*(BE+5.)*X2+17.	073410	0000
	UCH=SFA*SQRT(RS)*BE**2/2000.+(0.13*(BE-5.)*X2+14.)/AR	073420	0000
124	CONTINUE	073430	0000
	GO TO 800	073440	0000
C	MOLE EXCAVATION	073450	0000
220	UCL=0.021*BE**2+55.	073460	0000
	UCE=0.048*BE**2	073470	0000
	UCH=(5000.+RS+120000./AR)*BE**2/220000.	073480	0000
	GO TO 800	073490	0000
C	-----	073500	0000
C	SOFT GROUND TUNNEL	073510	0000
C	MOLED	073520	0000
320	UCL=(55.+0.021*BE**2)*CFLCA	073530	0000
	UCE=0.048*BE**2+0.000035*UTSHLD	073540	0000
	UCH=(0.045+0.02*HOURS/AR)*BE**2+(0.5+0.05*BE)*HOURS/AR	073550	0000
	GO TO 800	073560	0000
C	HAND EXCAVATED	073570	0000
420	UCL=(0.1*(BE+5.)*X2+30.)*CFLCA	073580	0000
	UCE=0.02*(BE+7.)*X2+0.000035*UTSHLD	073590	0000
	UCH=(0.5+0.25*BE)*HOURS/AR	073600	0000
	GO TO 800	073610	0000
C	RIPPER EXCAVATED	073620	0000
		073630	0000
		073640	0000

(Continued)

COSTEN Listing (Continued)

520	UCL=(50.+0.012(BE+4.))**2)*CFLCA	073650	0000
	UCE=12.+0.22E+0.000035*UTSHLD	073650	0000
	UCH=(2.0+0.002BE)*HOURS/AR	073670	0000
	GO TO 600	073680	0000
C	*****	073690	0000
C	CUT AND COVER	073700	0000
620	IF(DROCK.GE.DTRNCH) GO TO 700	073710	0000
C	OPEN CUT INVOLVING ROCK EXCAVATION	073720	0000
	UROCK=BE*(DTRNCH-DROCK)/27.	073730	0000
	UCLROK=71.+0.55*AR*UROCK/HOURS	073740	0000
	UCEROK=15.+(0.4+0.0035*DTRNCH)*AR*UROCK/HOURS	073750	0000
	UCHROK=(1.1+0.0006*(DTRNCH+DROCK))*UROCK	073760	0000
	IF(UCLROK.LT.84.75) UCLROK=84.75	073770	0000
	IF(AR*UROCK/HOURS.LT.25.) UCEROK=15.+(0.4+0.0035*DTRNCH)*25.	073780	0000
	IF(DROCK.GT.0.) GO TO 650	073790	0000
C	ALL ROCK , NO SOIL EXCAVATION	073800	0000
	USOIL=0.	073810	0000
	DCENT=0.	073820	0000
	UCLSOIL=0.	073830	0000
	UCESOL=0.	073840	0000
	UCMSOL=0.	073850	0000
	GO TO 750	073860	0000
C	SOME ROCK, SOME SOIL EXCAVATION	073870	0000
C	-----	073880	0000
C	SOIL EXCAVATION	073890	0000
650	USOIL=(BE+DROCK*SIDESL)*DROCK/27.	073900	0000
	DCENT=DROCK*(1.5*BE+DROCK*SIDESL)/(BE+DROCK*SIDESL)/3.	073910	0000
	IF(SIDESL.LT.1.) GO TO 670	073920	0000
	IF(AR*USOIL/HOURS.LE.500.) GO TO 670	073930	0000
C	SOIL EXCAVATED BY SCRAPERS	073940	0000
660	SCRAPR=AR*USOIL/HOURS/(290.-0.9*DCENT)	073950	0000
	IF(SCRAPR.LT.1.) SCRAPR=1.	073960	0000
	PUSHER=SCRAPR/4.	073970	0000
	IF(PUSHER.LT.1.) PUSHER=1.	073980	0000
	UCLSOIL=17.+8.0*(SCRAPR+PUSHER)	073990	0000
	UCESOL=19.*SCRAPR+10.*PUSHER	074000	0000
	UCMSOL=(5.5*SCRAPR+3.0*PUSHER)*HOURS/AR	074010	0000
	GO TO 750	074020	0000
C	SOIL EXCAVATED BY DRAGLINE	074030	0000
670	BUCKIN=10.-0.7*SQRT(160.-DROCK)	074040	0000
680	BUCKET=2.5*(AR*USOIL/HOURS/(1.05-0.00014*(PHI-50.))**2)-40.)	074050	0000
	1 / (170.-DCENT)	074060	0000
	IF(BUCKET.LT.BUCKIN) BUCKET=BUCKIN	074070	0000
	UCLSOIL=19.0	074080	0000
	UCESOL=13.0+0.85*BUCKET**2	074090	0000
	UCMSOL=1.12*BUCKET*USOIL/(40.+0.4*(170.-DCENT)*BUCKET)	074100	0000
	1 / (1.05-0.00014*(PHI-50.))**2)	074110	0000
	GO TO 750	074120	0000
C	-----	074130	0000
C	SOIL EXCAVATION ONLY, NO ROCK EXCAVATION	074140	0000
700	UROCK=0.	074150	0000
	UCLROK=0.	074160	0000
	UCEROK=0.	074170	0000
	UCHROK=0.	074180	0000
	USOIL=(BE+DTRNCH*SIDESL)*DTRNCH/27.	074190	0000
	DCENT=DTRNCH*(1.5*BE+DTRNCH*SIDESL)/(BE+DTRNCH*SIDESL)/3.	074200	0000
	IF(SIDESL.LT.1) GO TO 720	074210	0000
	IF(AR*USOIL/HOURS.GT.500.) GO TO 660	074220	0000

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COSTUM Listing (Continued)

720	BUCHIN=10.-0.7*50RT(160.-DTRNCH)	374230	0000
	GO TO 680	074240	0000
C	-----	074250	0000
C	COSTS OF BACKFILL	074260	0000
750	U=UROCK+USOIL	074270	0000
	UCLBAK=82.0	074280	0000
	UCEBAK=32.0	074290	0000
	IF(AR*(U-UBOX)/HOURS.LE.1200.) GO TO 760	074300	0000
	UCLBAK=82.*X(U-UBOX)*AR/HOURS/1200.	074310	0000
	UCEBAK=32.*X(U-UBOX)*AR/HOURS/1200.	074320	0000
760	UCMBAK=0.01*(U-UBOX)	074330	0000
	UCL=UCLROK+UCLSOL+UCLBAK	074340	0000
	UCE=UCEROK+UCESOL+UCEBAK	074350	0000
	UCM=UCMROK+UCMSOL+UCMBAK	074360	0000
	GO TO 800	074370	0000
C	*****	074380	0000
C	CALCULATE UNIT COSTS OF SHAFT EXCAVATION	074390	0000
100	IF(NSTYP.EQ.3) GO TO 500	074400	0000
	GO TO (140,240,340,440),MEX	074410	0000
C	ROCK SHAFT	074420	0000
C	CONVENTIONAL	074430	0000
140	UCL=30.+4.25*BE	074440	0000
	UCE=8.+2.2*BE	074450	0000
	UCM=(0.01+RS/2000000.)*BE**2 + (.8+RS/40000.+3.4/AR)*BE + 5.	074460	0000
	GO TO 800	074470	0000
	MOLED	074480	0000
240	UCL=0.032*BE**2+84.	074490	0000
	UCE=0.072*BE**2	074500	0000
	UCM=(5000.+RS+120000./AR)*BE**2/150000.	074510	0000
	GO TO 800	074520	0000
C	-----	074530	0000
C	SOFT GROUND SHAFT	074540	0000
C	MOLED	074550	0000
340	UCL=(0.032*BE**2+84.0)*CFLCA	074560	0000
	UCE=0.072*BE**2+0.000035*WTSGLD	074570	0000
	UCM=(0.045+0.03*HOURS)*BE**2+(0.5+0.05*BE)*HOURS/AR	074580	0000
	GO TO 800	074590	0000
C	HAND/SHIELD	074600	0000
440	IF(ISHAPE.EQ.1) UCL=63.0*CFLCA	074610	0000
	IF(ISHAPE.EQ.2) UCL=70.0*CFLCA	074620	0000
	UCE=7.40+0.000035*WTSGLD	074630	0000
	UCM=(3.70+0.05*BE)*HOURS/AR	074640	0000
800	CLE=UCL*(HOURS*CFLWUK+Y*DM)/AR	074650	0000
	CEE=UCE*HOURS*CFLWUK/AR	074660	0000
	CME=UCM	074670	0000
	GO TO 900	074680	0000
C		074690	0000
500	CLE=0.	074700	0000
	CEE=0.	074710	0000
	CME=0.	074720	0000
C		074730	0000
900	RETURN	074740	0000
	END	074750	0000
	SUBROUTINE CMUKLD(CML,CEML,CMML,ITYPE,MEX,AR,DM,U,Y,RMY,RMLMAX,	074760	0000
1	HSTAB,CFLCA,CFLWUK,CFEWUK,HOURS)	074770	0000
C	-----	074780	0000
C		074790	0000
C	CMUKLD CALCULATES THE COST OF MUCK LOADING IN TUNNELS AND SHAFTS	074800	0000

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COSTUN Listing (Continued)

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C ----- 074813 0000
C ----- 074823 0000
C IF(MEX.EQ.1.OR.MEX.EQ.4) GO TO 100 074833 0000
C ----- 074843 0000
C LOADING COSTS ARE ZERO FOR MOLE OR RIPPER EXCAUPTION AND FOR 074853 0000
C CUT-AND-COVER SEGMENTS 074863 0000
50 CLML=0 074873 0000
CEML=0 074883 0000
CHML=0 074893 0000
GO TO 300 074903 0000
C ----- 074913 0000
C CHECK FOR TUNNEL OR SHAFT 074923 0000
100 IF(ITYPE.EQ.2) GO TO 200 074933 0000
C ----- 074943 0000
C TUNNELS 074953 0000
UCL=9.30*CFLCA 074963 0000
UCE=3.50 074973 0000
IF(RMLMAX.GT.100.) UCE=6.60 074983 0000
IF(RMLMAX.GT.300.) UCE=12.90 074993 0000
UCH=0.02 075003 0000
GO TO 250 075013 0000
C ----- 075023 0000
C SHAFTS 075033 0000
200 IF (MEX.EQ.4) GO TO 50 075043 0000
UCL=9.30*CFLCA 075053 0000
UCE=3.50 075063 0000
UCH=1.50 075073 0000
C ----- 075083 0000
C CALCULATE MUCK LOADING COSTS 075093 0000
250 CLML=UCL*(HOURS*CFLWUK+Y*DM)/AR 075103 0000
CEML=UCE*HOURS*CFLWUK/AR 075113 0000
CHML=UCH*Y 075123 0000
300 RETURN 075133 0000
END 075143 0000
SUBROUTINE CMTAH(CMLT,CEMT,CMHT,CLMH,CEMH,CMMH,ITYPE,MTM,DM,AR, 075153 0000
1HSFA,U,HH,LINING,RML,RMLMAX,HSLOPE,BE,ISHAPE,RL,UCLT,UCET,V,UCLMH, 075163 0000
2HSCA,UCEMH,MSTAB,DLOCK,CLIND,HOURS,OPEN,DCENT,UBACEX,UBACDS,UBOX, 075173 0000
3 USOIL,UROCK,TOTBOX,CFLWUK,CFLWUK,CFLCA,DDS,NSTYP,DTRNCH,DROCK) 075183 0000
C ----- 075193 0000
C CMTAH CALCULATES MUCK TRANSPORT COSTS IN TUNNELS AND MUCK HOISTING 075203 0000
C COSTS IN TUNNELS AND SHAFTS. IT ALSO CALCULATES COST OF TRANSPORT 075213 0000
C FOR BACKFILL IN CUT-AND-COVER TUNNEL. 075223 0000
C ----- 075233 0000
C SHAFT OR TUNNEL 075243 0000
C IF(ITYPE.EQ.2) GO TO 600 075253 0000
C ----- 075263 0000
C IF(NSTYP.EQ.3) GO TO 2000 075273 0000
C COST OF MUCK TRANSPORT IN TUNNELS 075283 0000
C GO TO (20,60,40,80),MTM 075293 0000
C ----- 075303 0000
C TRUCK TRANSPORT Z= TRUCK VOLUME/4 075313 0000
20 IF(ISHAPE.LE.2) Z=5.0 - 0.001*(70. - BE)**2 075323 0000
IF(ISHAPE.EQ.3) Z=4.5 - 0.5*(BE-50.)**4/22000. 075333 0000
TRUCKS=0.063*RMLMAX/Z*DM**0.7 075343 0000
IF(TRUCKS.LT.1.) TRUCKS=1. 075353 0000
C ----- 075363 0000

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COSTUN Listing (Continued)

	UCL=7.7*TRUCKS+7.1	075390 0000
	UCE=(1.5+3.1*Z)*TRUCKS	075400 0000
	UCH=0.05*(1.+0.77*ABS(HSLOPE))*DM	075410 0000
	GO TO 400	075420 0000
C	-----	075430 0000
C	RAIL TRANSPORT - FREE AIR	075440 0000
C	CALCULATION OF NUMBER OF CARS	075450 0000
40	CONTINUE	075460 0000
	CARS=(0.06+0.12*DM**0.33)*RMLMAX	075470 0000
1	+ AR/300.*(0.06+0.023*DM-0.12*DM**0.33)*RMLMAX	075480 0000
	IF(MSTAB.EQ.1) GO TO 1000	075490 0000
44	IF(CARS.LT.1.) CARS=1.	075500 0000
C	-----	075510 0000
C	CALCULATION OF NUMBER OF ENGINES	075520 0000
	ENGINE=CARS/11.	075530 0000
55	IF(ENGINE.LT.1.) ENGINE=1.	075540 0000
	UCL=15.*ENGINE+7.14*(DM+1.)*AR/12.	075550 0000
	UCE=5.8*ENGINE+CARS+1.4*DM	075560 0000
	UCH=0.03*DM	075570 0000
	GO TO 400	075580 0000
C	-----	075590 0000
C	RAIL TRANSPORT - COMPRESSED AIR	075600 0000
C	-----	075610 0000
1000	DCR=0.1*DM*5280.	075620 0000
	DCA=DM-DLOCK/5280.	075630 0000
	IF(DCR.GT.500.) DCR=500.	075640 0000
	CARS=(1.+0.7/(DM+2.))*CARS	075650 0000
	IF(CARS.LT.1.) CARS=1.	075660 0000
	ENGINE=CARS/11.	075670 0000
	IF(ENGINE.LT.1.) ENGINE=1.	075680 0000
C	CALCULATE NUMBER OF CREWS INSIDE AND OUTSIDE THE AIR LOCK	075690 0000
	CREWAD=1.-ENGINE**4/4000.	075700 0000
	IF(CREWAD.LT.0.) CREWAD=0.	075710 0000
	CREUS=ENGINE+CREWAD	075720 0000
	CREUCA=1.+(CREUS-2.)*(DM*5280.-DLOCK-0.5*DCR)/(DM*5280.-1.5*DCR)	075730 0000
	IF(DLOCK.LT.DCR) CREUCA=CREUS-1.	075740 0000
	IF(DM*5280.-DLOCK.LT.0.5*DCR) CREUCA=1.	075750 0000
	UCL=1.5*(CREUS+(CFLCA-1.)*CREUCA)+AR*CFLCA/12.	075760 0000
1	+7.14*(DM+1.)*(DLOCK/5280.+DCA*CFLCA)/DM	075770 0000
	UCE=9.3*ENGINE+CARS+1.4*DM	075780 0000
	UCH=0.033*DM	075790 0000
	GO TO 400	075800 0000
C	-----	075810 0000
C	CONVEYOR TRANSPORT - FREE AIR	075820 0000
60	UCL=(0.013*AR+0.6*DM)*SQRT(RMLMAX+40.)*0.06*AR-1.1*DM	075830 0000
	IF(HSLOPE.GE.0.0) UCECON=((1.+4.*HSLOPE)*SQRT(RMLMAX+40.))-26.*	075840 0000
1	HSLOPE-1.5)*DM	075850 0000
	IF(HSLOPE.LT.0.0) UCECON=(SQRT(RMLMAX+40.))+6.*HSLOPE-1.5)*DM	075860 0000
	IF(HSLOPE.GE.0.0) UCHCON=(0.01+0.23*HSLOPE)*DM	075870 0000
	IF(HSLOPE.LT.0.0) UCHCON=0.01*DM	075880 0000
	UCENT=0.	075890 0000
	UCHNT=0.	075900 0000
C	-----	075910 0000
	IF(MSTAB.NE.1) GO TO 1100	075920 0000
C	CONVEYOR TRANSPORT - COMPRESSED AIR	075930 0000
	DCA=DM-DLOCK/5280.	075940 0000
	UCL=UCL*(DLOCK/5280.+DCA*CFLCA)/DM+7.7*CFLCA+16.8	075950 0000
C	COST OF MUCK TRANSFER IN AIR LOCK	075960 0000

(Continued)

COSTUM Listing (Continued)

	UCENT=8.10	075970	0000
	IF(RMLMAX.LE.100.) UCENT=4.50	075980	0000
	IF(RMLMAX.GT.300.) UCENT=14.90	075990	0000
	UCMNT=0.02	076000	0000
1100	UCE=UCECON+UCENT	076010	0000
	UCM=UCMCON+UCMNT	076020	0000
C	STORE COST VALUES FOR USE IN LINING COMPUTATIONS (SUB LINING)	076030	0000
	UCLT=(0.6*SQRT(RMLMAX+40.))-1.1)*XDM	076040	0000
	UCET=UCE	076050	0000
	GO TO 400	076060	0000
C	-----	076070	0000
C	CONVEYOR AND TRUCK (FOR COMPRESSED AIR SEGMENT ONLY)	076080	0000
80	IF(MSTAB.NE.1) GO TO 20	076090	0000
	IF(DLOCK.LE.0.001) GO TO 60	076100	0000
	DCA=DM-DLOCK/5280.	076110	0000
C	TRUCKS IN FREE AIR	076120	0000
	IF(ISHAPE.LE.2) Z=5.0 - 0.001*(70. - BE)**2	076130	0000
	IF(ISHAPE.EQ.3) Z=4.5 - 0.5*(BE-50.)*4/22000.	076140	0000
	TRUCKS=0.06*RMLMAX/Z*(DLOCK/5280.)*X0.7	076150	0000
	IF(TRUCKS.LT.1.) TRUCKS=1.	076160	0000
	UCETR=(1.5+3.1*Z)*TRUCKS	076170	0000
	UCMTR=0.05*(1.+0.77*ABS(HSFA))*DLOCK/5280.	076180	0000
C	CONVEYOR IN COMPRESSED AIR	076190	0000
	UCECON=DCA*((1.+4.*HSCA))*SQRT(RMLMAX+40.)*-26.*HSCA -1.5)	076200	0000
	UCMCON=DCA*(0.01+0.23*HSCA)	076210	0000
	IF(HSCA .GE.0.) GO TO 1200	076220	0000
	UCECON=DCA*(SQRT(RMLMAX+40.))+6.*HSCA -1.5)	076230	0000
	UCMCON=0.01*DCA	076240	0000
C	COST OF MUCK TRANSFER IN AIR LOCK	076250	0000
1200	UCENT=8.10	076260	0000
	IF(RMLMAX.LE.100.) UCENT=4.50	076270	0000
	IF(RMLMAX.GT.300.) UCENT=14.9	076280	0000
	UCMNT=0.02	076290	0000
	UCL=((0.013*AR+0.6*DCA)*SQRT(RMLMAX+40.))+0.06*AR-1.1*DCA)*CFLCA	076300	0000
1	+7.7*(TRUCKS+CFLCA)+23.9*CLIND*AR/HOURS	076310	0000
	UCE=UCECON+UCENT+UCETR	076320	0000
	UCM=UCMCON+UCMNT+UCMTR	076330	0000
C	-----	076340	0000
C	CALCULATE MUCK TRANSPORT COSTS	076350	0000
C	-----	076360	0000
400	CLMT=UCL*HOURS*CFLWUK/AR	076370	0000
	CENT=UCE*HOURS/AR*CFLWUK	076380	0000
	CMNT=UCM*U	076390	0000
	IF(HH.GT.0.) GO TO 500	076400	0000
C	SHAFT IS A PORTAL, HOISTING COSTS ARE ZERO	076410	0000
300	UCL=0.	076420	0000
	UCE=0.	076430	0000
	UCM=0.	076440	0000
	UCLIND=0.	076450	0000
	GO TO 700	076460	0000
C	COST OF BACKFILL TRANSPORT IN CUT AND COVER	076470	0000
2000	DCENT=(DCENT*USOIL-UBOX*(DTRNCH-TOTBOX/2.))/(U-UBOX)	076480	0000
	IF(DROCK.LT.DTRNCH) DCENT=DCENT+UROCK*(DTRNCH+DROCK)/2./(U-UBOX)	076490	0000
	TRUCKS=(0.02+(OPEN+DCENT/0.1)/75000.)*UBACE*(U-UBOX)*AR/HOURS	076500	0000
	IF(TRUCKS.LT.1.) TRUCKS=1	076510	0000
	UCL=(10.+(15.5+4.7*DDS)*UBACDS*(U-UBOX)*AR/1000.)*24./HOURS	076520	0000
1	+8.20+6.25*TRUCKS	076530	0000
		076540	0000

(Continued)

COSTUN Listing (Continued)

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      UCE=(6.+(12.5+2.1*DDS)*UBACDS*(U-UBOX)*AR/1000.)*24./HOURS      076550 0000
1      +8.40+2.70*TRUCKS      076553 0000
      UCM=0.055*DDS*UBACDS+0.00005*(OPEN+DCENT/0.1)*UBACEX      076570 0000
1      +2.2*HOURS/AR/(U-UBOX)      076580 0000
C      CALCULATE COST OF BACKFILL TRANSPORT PER FOOT OF TUNNEL      076590 0000
      CLMT=UCL*HOURS/AR*CFLOWK      076600 0000
      CEMT=UCE*HOURS/AR*CFEWWK      076610 0000
      CMMT=UCM*(U-UBOX)      076620 0000
C      RESET UNIT COSTS TO ZERO SO MUCK HOISTING COST WILL BE ZERO IN      076630 0000
C      CUT-AND-COVER      076640 0000
      GO TO 300      076650 0000
C      *****      076660 0000
C      CALCULATE UNIT COST OF MUCK HOISTING IN TUNNELS      076670 0000
500      UCL=35.+0.003*HH*(1.+0.002*RMLMAX)+0.016*RMLMAX      076680 0000
      UCE=10. + 0.03*RMLMAX      076690 0000
      UCM=0.05      076700 0000
      UCLIND=(50000.+0.04*(900.+HH)*RMLMAX)/RL      076710 0000
      GO TO 700      076720 0000
-----
C      CALCULATE UNIT COST OF MUCK HOISTING IN SHAFTS      076730 0000
C      600      UCL=0.      076740 0000
      UCE=0.      076750 0000
      UCM=0.      076760 0000
      UCLIND=0.      076770 0000
      IF(NSTYP.EQ.3) GO TO 800      076780 0000
      UCL=29. + 0.002*HH*(1.+0.002*RMLMAX)      076790 0000
      UCE=3.+0.04*RMLMAX      076800 0000
      UCM=0.05      076810 0000
      UCLIND=0.      076820 0000
-----
C      CALCULATE MUCK HOISTING COSTS      076830 0000
C      700      CLMH=(HOURS*UCL/AR+UCLIND)*CFLOWK      076840 0000
      CEMH=HOURS*UCE/AR*CFEWWK      076850 0000
      CMMH=UCM*U*HH/1000.      076870 0000
      GO TO 750      076880 0000
800      CLMH=0.      076890 0000
      CEMH=0.      076900 0000
      CMMH=0.      076910 0000
750      CONTINUE      076920 0000
C      STORE COST VALUES FOR USE IN LINING COMPUTATION      076930 0000
      UCLMH=UCL      076940 0000
      UCEMH=UCE      076950 0000
C      076960 0000
      RETURN      076970 0000
      END      076980 0000
      SUBROUTINE CMUKDP(CLMD,CEMD,CMMD,AR,U,CDS,DDS,UDS,NSTYP,HOURS,      076990 0000
1      CFLWUK,CFEWWK,ITYPE)      077000 0000
-----
C      CMUKDP CALCULATES THE COST OF MUCK DISPOSAL FOR TUNNELS AND SHAFTS      077010 0000
C      077020 0000
C      077030 0000
C      077040 0000
C      077050 0000
C      077060 0000
C      077070 0000
C      077080 0000
C      077090 0000
C      077100 0000
C      077110 0000
      IF(ITYPE.EQ.2.AND.NSTYP.EQ.3) GO TO 100
      CALCULATE UNIT COST OF MUCK DISPOSAL
      UNKDP=U

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COSTUN Listing (Continued)

	IF (NSTYP.EQ.3) UMKDP=UDSZU	077120	0000
	UCL=(10.+(15.5+4.7*DDS)*UMKDP*AR/1000.)*24./HOURS	077130	0000
	UCE=(10.+(12.5+2.1*DDS)*UMKDP*AR/1000.)*24./HOURS	077140	0000
	UCH=0.055*DDS	077150	0000
	UCDS=CD\$*UMKDP*0.00003	077160	0000
C	CALCULATE COST OF MUCK DISPOSAL	077170	0000
	CLMD=UCL*HOURS/AR*CFLWUK	077180	0000
	CEND=UCE*HOURS/AR*CFEUUK	077190	0000
	CMMD=UCDS+UCH*UMKDP	077200	0000
	GO TO 200	077210	0000
C		077220	0000
100	CLMD=0.	077230	0000
	CEND=0.	077240	0000
	CMMD=0.	077250	0000
C		077260	0000
200	RETURN	077270	0000
	END	077280	0000
	SUBROUTINE CTSUP (CLTS, CETS, CMTS, RQD, MEX, ISHAPE, BE, AR, RS, BE40, BE60	077290	0000
	1, ITYPE, Y, DM, NSTYP, BF, ISUPPT, TPLATE, TSEG, PSOIL, LEB, PTOTAL,	077300	0000
	2BOB, LINUT, NSTAB, CFLCA, HOURS, CFLWUK, CFEUUK, DSLURY, DTANCH, IDECK,	077310	0000
	3DROCK, WTSTRT, UTWALE, SPDLT, UTSPD, WTSP, WTANCH, TOTBOX, IBRACE, SFA)	077320	0000
C	-----	077330	0000
C	CTSUP CALCULATES THE COST OF SUPPORTS IN TUNNELS AND SHAFTS	077340	0000
C	-----	077350	0000
C	IS IT A ROCK TUNNEL OR SHAFT	077360	0000
C	IF (NSTYP.EQ.1) GO TO 5	077370	0000
C	II IS A FLOW INDICATOR	077380	0000
C	II=4	077390	0000
C	IS IT A SOFT GROUND TUNNEL OR SHAFT	077400	0000
C	IF (NSTYP.EQ.2) GO TO 1000	077410	0000
C	GO TO 1500	077420	0000
C		077430	0000
C	-----	077440	0000
C	*****	077450	0000
C	ROCK TUNNELS AND SHAFTS	077460	0000
C	*****	077470	0000
C		077480	0000
5	IF (ITYPE.EQ.2) ISHAPE=1	077490	0000
	E=2.71828	077500	0000
	IF (RQD.GT.40..AND.RQD.LT.60.) GO TO 10	077510	0000
	IF (RQD.LE.40.) GO TO 40	077520	0000
C	RQD .GE. 60 ROCK BOLTS USED	077530	0000
20	II=4	077540	0000
510	GO TO (200,210),MEX	077550	0000
C	CONVENTIONAL EXCAVATION	077560	0000
200	IF (ISHAPE.LT.3) GO TO 220	077570	0000
C	-----	077580	0000
C	F IS A ROCK BOLT WEIGHT FACTOR, FF IS A WIRE MESH WEIGHT FACTOR	077590	0000
C	SHAPE IS BASKETHANDLE	077600	0000
C	F=1.6	077610	0000
	FF=0.74	077620	0000
	GO TO 230	077630	0000
C	SHAPE IS CIRCLE OR HORSESHOE	077640	0000
220	F=1.0	077650	0000
	FF=1.0	077660	0000
	GO TO 230	077670	0000
C	MOLE EXCAVATION	077680	0000
		077690	0000

(Continued)

COSTUN Listing (Continued)

210	F=0.56	077700	0000
	FF=1.0	077710	0000
C	CALCULATE WEIGHT OF ROCK BOLTS	077720	0000
230	URB=(F*0.56*BE**((0.026*BE)*(100-RQD)**2)/(152.-RQD)**2	077730	0000
	GO TO(240,250), ITYPE	077740	0000
C	CALCULATE WEIGHT OF WIRE MESH IN TUNNELS	077750	0000
240	UWM=FF*3.3*BE*(1.-0.01*RQD)	077760	0000
C	-----	077770	0000
C	UNIT COSTS OF ROCK BOLT SUPPORTS IN TUNNELS	077780	0000
	UCL=0.02*URB*AR	077790	0000
	IF(BE.LE.16.) UCE=1.76	077800	0000
	IF(BE.GT.16..AND.URB*AR.LE.1000.) UCE=9.35	077810	0000
	IF(BE.GT.16..AND.URB*AR.GT.1000.) UCE=9.35+0.0023*(URB*AR-1000.)	077820	0000
	UCM=0.32*UWM+(0.23+RS/530000.)*URB	077830	0000
	GO TO 300	077840	0000
C	-----	077850	0000
C	WEIGHT OF WIRE MESH IN SHAFTS	077860	0000
250	UWM=FF*4.*BE	077870	0000
C	-----	077880	0000
C	UNIT COSTS OF ROCK BOLT SUPPORTS IN SHAFTS	077890	0000
	UCL=0.0	077900	0000
	IF(MEX.EQ.1) UCE=0.0	077910	0000
	IF(MEX.EQ.2) UCE=1.76	077920	0000
	UCM=0.32*UWM+(0.23+RS/530000.)*URB	077930	0000
	GO TO 300	077940	0000
C	-----	077950	0000
C	RQD IS BETWEEN 40 AND 60, INTERPOLATION OF COSTS IS NECESSARY.	077960	0000
C	COST WILL BE COMPUTED FOR RQD=40 AND THEN FOR RQD=60 BEFORE	077970	0000
C	INTERPOLATING TO OBTAIN COSTS AT ACTUAL RQD.	077980	0000
C	-----	077990	0000
C	STORE THE CORRECT VALUES OF RQD AND BE	078000	0000
10	RQDD=RQD	078010	0000
	BBE=BE	078020	0000
C	ESTABLISH FICTITIOUS VALUES OF RQD AND SIZE FOR INTERPOLATION USE	078030	0000
	BE=BE40	078040	0000
	RQD=40	078050	0000
	II=1	078060	0000
	GO TO 410	078070	0000
C	RQD .LE. 40 STEEL SETS USED	078080	0000
40	II=4	078090	0000
410	GO TO (420,430,440), ISHAPE	078100	0000
C	SHAPE IS CIRCLE	078110	0000
420	GO TO (450,460), MEX	078120	0000
C	-----	078130	0000
C	FACTOR FOR WEIGHT OF STEEL SUPPORTS=F	078140	0000
C	CONVENTIONAL EXCAVATION	078150	0000
450	F=0.56*((RQD-20.)/100.)*2+1.22	078160	0000
C	FBL= FACTOR FOR BLOCKING AND LAGGING	078170	0000
	FBL=1.0	078180	0000
	GO TO 470	078190	0000
C	MOLE EXCAVATION	078200	0000
460	F=1.0	078210	0000
	FBL=0.81	078220	0000
C	WEIGHT OF STEEL SUPPORTS	078230	0000
470	WST=F*EXX(SQRT(ABS(0.7*BE-6.))+3.7-2*((RQD+20.)/100.)*2)	078240	0000
	GO TO 480	078250	0000
C	SHAPE IS HORSESHOE	078260	0000
430	WST=EXX(SQRT(ABS(0.85*BE-7.))+0.8+0.3*SQRT(100.-RQD))	078270	0000

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COSTUM Listing (Continued)

	FBL=1.+0.012*BE	078280	0000
	GO TO 480	078290	0000
C	SHAPE IS BASKETHANDLE	078300	0000
440	WST=XXX(SQRT(ABS(0.92*BE-6.))+0.82+0.22*SQRT(100.-RQD))	078310	0000
	FBL=1.+0.003*BE	078320	0000
C	QUANTITY OF BLOCKING AND LAGGING	078330	0000
480	BL=FBL*BE*(0.0018+0.0056*((117.-RQD)/100.))*2)	078340	0000
	GO TO (490,500),ITYPE	078350	0000
C	-----	078360	0000
C	UNIT COSTS OF STEEL SUPPORTS IN TUNNELS	078370	0000
490	IF(MEX.EQ.1) VV=1.1	078380	0000
	IF(MEX.EQ.2) VV=1.0	078390	0000
	UCL=VV*(0.001*WST*AR+0.4*BE)	078400	0000
	UCE=VV*(6.+0.0002*WST*AR)	078410	0000
	UCM=36.*VV/AR+0.095*WST+150.*BL	078420	0000
	GO TO 300	078430	0000
C	-----	078440	0000
C	UNIT COSTS OF STEEL SUPPORTS IN SHAFT	078450	0000
500	UCL=1.1/3.*(0.001*WST*AR+0.4*BE)	078460	0000
	UCE=1.1/3.*(6.+0.0002*WST*AR)	078470	0000
	UCM=0.095*WST+150.*BL	078480	0000
C	-----	078490	0000
C	COST OF SUPPORTS	078500	0000
C		078510	0000
300	CLTS=(HOURS*CFLOWK+V*DM)*UCL/AR	078520	0000
	CETS=HOURS*CFEWWK*UCE/AR	078530	0000
	CMTS=UCM	078540	0000
C	-----	078550	0000
	IF(II.GE.3) GO TO 700	078560	0000
	IF(II.GE.2) GO TO 600	078570	0000
C	STORE COSTS COMPUTED USING FICTITIOUS RQD=40	078580	0000
	CL40=CLTS	078590	0000
	CE40=CETS	078600	0000
	CM40=CMTS	078610	0000
C	REDEFINE RQD TO A FICTITIOUS VALUE OF 60 FOR SECOND PART OF	078620	0000
C	INTERPOLATION COMPUTATION	078630	0000
	RQD=60	078640	0000
	BE=BE60	078650	0000
C	REDEFINE FLOW INDICATOR	078660	0000
	II=II+1	078670	0000
	GO TO 510	078680	0000
C	STORE COSTS COMPUTED USING FICTITIOUS RQD=60	078690	0000
600	CL60=CLTS	078700	0000
	CE60=CETS	078710	0000
	CM60=CMTS	078720	0000
C	-----	078730	0000
C	INTERPOLATE BETWEEN RQD OF 40 AND 60 TO OBTAIN SUPPORT COSTS	078740	0000
	CLTS=CL40+((RQDD-40)/20)*(CL60-CL40)	078750	0000
	CETS=CE40+((RQDD-40)/20)*(CE60-CE40)	078760	0000
	CMTS=CM40+((RQDD-40)/20)*(CM60-CM40)	078770	0000
C	-----	078780	0000
C	REINSTATE ORIGINAL VALUES OF RQD AND BE	078790	0000
	RQD=RQDD	078800	0000
	BE=BE	078810	0000
700	RETURN	078820	0000

(Continued)

COSTUN Listing (Continued)

C	*****	078830	0000
C	SOFT GROUND TUNNELS OR SHAFTS	078840	0000
C	*****	078850	0000
C	ESTABLISH SHAPE FACTOR BASED ON PERIMETER	078860	0000
1000	IF(ITYPE.EQ.2) GO TO 1035	078870	0000
	GO TO(1010,1020,1030),ISHAPE	078880	0000
C	CIRCULAR	078890	0000
1010	SFP=3.14	078900	0000
	GO TO 1050	078910	0000
C	HORSESHOE	078920	0000
1020	SFP=3.57	078930	0000
	GO TO 1050	078940	0000
C	BASKETHANDLE	078950	0000
1030	SFP=2.66	078960	0000
	GO TO 1050	078970	0000
C	SHAFT SEGMENT	078980	0000
1035	IF(ISHAPE.EQ.1) GO TO 1010	078990	0000
C	SQUARE	079000	0000
	SFP=4	079010	0000
1050	PERMTR=0.5*(DE+BF)*SFP	079020	0000
	GO TO(1060,1070,1080,1300),ISUPPT	079030	0000
C	SEGMENTED CAST IRON OR STEEL SUPPORTS	079040	0000
1060	S=3	079050	0000
	GO TO 1080	079060	0000
C	SEGMENTED CONCRETE SUPPORTS	079070	0000
1070	S=4	079080	0000
1080	TWED=TPLATE	079090	0000
	IF(TWED.GT.1.) TWED=1	079100	0000
	AREA=S*TPLATE+2.*TWED*(TSEG-TPLATE)	079110	0000
C	CALCULATE SUPPORT QUANTITIES	079120	0000
	GO TO(1110,1120,1190),ISUPPT	079130	0000
C	-----	079140	0000
C	SEGMENTED CAST IRON SUPPORTS	079150	0000
1110	UCI=450.*(AREA+0.667*(S-2.*TWED)*(TSEG-TPLATE)*TWED)/S*PERMTR	079160	0000
	YY=0.13*UCI	079170	0000
	GO TO 1200	079180	0000
C	-----	079190	0000
C	SEGMENTED CONCRETE SUPPORTS	079200	0000
1120	UL=1./27.*(AREA+0.667*(S-2.*TWED)*(TSEG-TPLATE)*TWED)/S*PERMTR	079210	0000
	IF(ITYPE.EQ.2) GO TO 1175	079220	0000
C	TUNNEL SEGMENT	079230	0000
	GO TO(1150,1160,1170),ISHAPE	079240	0000
C	CIRCULAR	079250	0000
1150	RST=0.01	079260	0000
	GO TO 1185	079270	0000
C	HORSESHOE	079280	0000
1160	RST=0.032-0.16E-6*S*PTOTAL	079290	0000
	PMINT=54000./BF**1.5	079300	0000
	RSTMNT=0.032-0.16E-6*PMINT	079310	0000
	GO TO 1180	079320	0000
C	BASKETHANDLE	079330	0000
1170	RST=0.032-0.16E-6*S*PTOTAL	079340	0000
	PMINT=60000./BF**1.7	079350	0000
		079360	0000
		079370	0000

(Continued)

COSTUN Listing (Continued)

	RSTMT=0.032-0.10E-6*PMINT	079380 0000
	GO TO 1180	079390 0000
C	SHAFT SEGMENT	079400 0000
1175	IF(ISHAPE.EQ.1) GO TO 1150	079410 0000
C	SQUARE	079420 0000
	RST=0.034-0.13E-6*PTOTAL	079430 0000
	PMINT=50000./3F1*1.9	079440 0000
	RSTMT=0.034-0.13E-6*PMINT	079450 0000
1180	IF(PTOTAL.LT.PMINT) RST=0.01+(RSTMT-0.01)/PMINT*PTOTAL	079460 0000
	IF(RST.LT.0.01) RST=0.01	079470 0000
1185	UREIN=491.*RST*XUL*27.	079480 0000
	YY=99.*UL+0.15*UREIN	079490 0000
	GO TO 1200	079500 0000
C	-----	079510 0000
C	SEGMENTED STEEL SUPPORTS	079520 0000
1190	UST=491.*(AREA+0.667*(S-2.*TWEB)*(TSEG-TPLATE)*TWEB)/S*PERMTR	079530 0000
	YY=0.095*UST	079540 0000
1200	IF(ITYPE.EQ.2) GO TO 1210	079550 0000
C	TUNNEL SEGMENT	079560 0000
	Y3=1	079570 0000
	GO TO 1230	079580 0000
C	SHAFT SEGMENT	079590 0000
C	IS COMPRESSED AIR USED	079600 0000
1210	IF(MSTAB.EQ.1) GO TO 1220	079610 0000
	Y3=0.333	079620 0000
	GO TO 1230	079630 0000
1220	Y3=1.25	079640 0000
1230	UCL=Y3*(50.+0.04*BE**2)*((CFLCA-1.)*2./3.+1.)	079650 0000
	IF(ITYPE.EQ.2) UCL=Y3*(50.+0.04*BE**2)	079660 0000
	UCE=Y3*(5.5+0.003*(BE+10.))*2	079670 0000
	UCH=Y3*(2.1+0.001*BE**2)*HOURS/AR+YY	079680 0000
C	-----	079690 0000
C	ADD COST FOR CAULKING SEGMENTED SUPPORTS IN WATERTIGHT TUNNELS	079700 0000
C	AND SHAFTS	079710 0000
	IF(LINUT.EQ.1) GO TO 1240	079720 0000
	GO TO 1250	079730 0000
1240	IF(ITYPE.EQ.2) GO TO 1250	079740 0000
C	TUNNEL SEGMENT	079750 0000
	IF(ISHAPE.EQ.1) GO TO 1260	079760 0000
C	HORSESHOE OR BASKETHANDLE	079770 0000
	SEGN=6	079780 0000
	GO TO 1270	079790 0000
1250	IF(ISHAPE.EQ.1) GO TO 1260	079800 0000
C	SQUARE	079810 0000
	SEGN=8	079820 0000
	GO TO 1270	

(Continued)

COSTUN Listing (Continued)

	GO TO 1270	079830	0000
C	CIRCULAR	079840	0000
1260	SEGN=3	079850	0000
1270	CJOINT=BE*SEFP/S+SEGN	079860	0000
	IF(ITYPE.EQ.1) UCL=UCL+0.175*CJOINT*AR*CFLCA/HOURS	079870	0000
	IF(ITYPE.EQ.2) UCL=UCL+0.175*CJOINT*AR/HOURS	079880	0000
	UCE=UCE+0.025*CJOINT*AR/HOURS	079890	0000
	UCH=UCH+0.3*CJOINT	079900	0000
	GO TO 1350	079910	0000
C	-----	079920	0000
C	STEEL RIB SUPPORT	079930	0000
1300	S=10.-0.65*ALOG(PSOIL)	079940	0000
	IF(S.GT.6.) S=6	079950	0000
	AREA=1./144.*EXP(4.26*SQRT (WEB-0.33))	079960	0000
	WST=401.*AREA*SEFP*(BE-WEB)/S	079970	0000
	BLTHCK=1./535.*SQRT(PSOIL)*(9.5-0.65*ALOG(PSOIL))	079980	0000
C	ASSUME MINIMUM LAGGING THICKNESS TO BE 5 INCHES	079990	0000
	IF(BLTHCK.LT.5./12.) BLTHCK=5./12.	080000	0000
	BL=BLTHCK*12.*SEFP*(BE-BLTHCK)/1000.	080010	0000
	IF(ITYPE.EQ.2) GO TO 1320	080020	0000
C	TUNNEL SEGMENT	080030	0000
	VV=1.1	080040	0000
	V3=39.6	080050	0000
	GO TO 1340	080060	0000
C	SHAFT SEGMENT	080070	0000
C	IS COMPRESSED AIR USED	080080	0000
1320	IF(MSTAB.EQ.1) GO TO 1330	080090	0000
	VV=1.1/3.	080100	0000
	V3=0	080110	0000
	GO TO 1340	080120	0000
1330	VV=1.4	080130	0000
	V3=50	080140	0000
1340	UCL=VV*(0.001*WST*AR+0.4*BE)*((CFLCA-1.)/2./3.+1.)	080150	0000
	IF(ITYPE.EQ.2) UCL=VV*(0.001*WST*AR+0.4*BE)	080160	0000
	UCE=VV*(6.+0.0002*WST*AR)	080170	0000
	UCH=V3/AR+0.095*WST+150.*BL	080180	0000
C	ADD COST FOR BACKFILL GROUT	080190	0000
1350	UBACKG=SEFP*(300**2-BE**2)	080200	0000
	IF(ITYPE.EQ.1) UCL=UCL+1.3*UBACKG*AR*CFLCA/HOURS	080210	0000
	IF(ITYPE.EQ.2) UCL=UCL+1.3*UBACKG*AR/HOURS	080220	0000
	UCE=UCE+0.5*UBACKG*AR/HOURS	080230	0000
	UCH=UCH+1.2*UBACKG	080240	0000
	GO TO 300	080250	0000
C	*****	080260	0000
C	CUT AND COVER	080270	0000
C	*****	080280	0000
C	*****	080290	0000
C	SET COSTS=0	080300	0000
1500	UCL=0	080310	0000
	UCE=0	080320	0000
	UCH=0	080330	0000
C	IS IT A SHAFT	080340	0000
	IF(ITYPE.EQ.1) GO TO 1505	080350	0000
	CLTS=0.	080360	0000
	CETS=0.	080370	0000

(Continued)

COSTUM Listing (Continued)

	CNTS=0.	080380	0000
	RETURN	080390	0000
C	FOR SLOPING CUT, ONLY COST OF ROCK BOLTS WILL BE COMPUTED	080400	0000
1505	IF(MEX.EQ.7) GO TO 1750	080410	0000
C	IF OPEN CUT IS ENTIRELY IN ROCK, ONLY COST OF ROCK BOLTS IS	080420	0000
C	COMPUTED FOR SUPPORTS	080430	0000
	IF(DROCK.LT.0.1) GO TO 1760	080440	0000
	DROOF=DTRNCH-TOTBOX	080450	0000
	IF(ISUPPT.EQ.6) GO TO 1510	080460	0000
	GO TO 1515	080470	0000
C	-----	080480	0000
C	SLURRY WALL	080490	0000
C	-----	080500	0000
1510	IF(DROCK.LE.DROOF-2.) SLURRY=0.5*DROCK/12.	080510	0000
	IF(DROCK.GT.DROOF-2.) SLURRY=0.5*DTRNCH/12.	080520	0000
	IF(SLURRY.LT.1.5) SLURRY=1.5	080530	0000
	UCL=UCL+145.*DSLURY*SLURRY/2600.*AR/HOURS	080540	0000
	UCE=UCE+181.*DSLURY*SLURRY/2600.*AR/HOURS	080550	0000
	UCM=UCM+(1.4*SLURRY-0.6)*DTRNCH*1.15	080560	0000
C	-----	080570	0000
C	WALES AND STRUTS	080580	0000
C	-----	080590	0000
C	WALERS AND STRUTS ARE SPACED 10 FEET VERTICALLY.	080600	0000
C	ACTUAL NUMBER OF STRUTS AND WALERS REQUIRED IS DSOIL/10 - 1	080610	0000
C	BECAUSE RESTRAINT AT BOTTOM OF SOLDIER PILE ACTS AS A STRUT.	080620	0000
C	IF ACTUAL NUMBER REQUIRED IS LESS THAN ONE, THEN USE ONE.	080630	0000
C	IS ROCK LINE ABOVE TRENCH BOTTOM	080640	0000
1515	IF(DROCK.LT.DTRNCH) GO TO 1520	080650	0000
	STRUT=(DTRNCH/10.-1.)/15.*BXWTSTRT	080660	0000
	IF(IBRACE.EQ.3) STRUT=(DROOF/10.-1.)/15.*BXWTSTRT	080670	0000
	WALE=(DTRNCH/10.-1.)*2.*WTWALE	080680	0000
	GO TO 1560	080690	0000
1520	STRUT=(DROCK/10.-1.)/15.*BXWTSTRT	080700	0000
	IF(IBRACE.EQ.3 .AND. DROOF.LT.DROCK) STRUT=(DROOF/10.-1.)/15.*	080710	0000
	1BXWTSTRT	080720	0000
C	IS DECKING REQUIRED	080730	0000
	IF(IDECK.EQ.1) GO TO 1540	080740	0000
	WALE=(DROCK/10.-1.)*2.*WTWALE	080750	0000
	GO TO 1560	080760	0000
1540	WALE=(DROCK/10.-1.)*2.*WTWALE+((DTRNCH-DROCK)/10.-1.)*2.*13.	080770	0000
C	VERTICAL CUTS IN SOIL LESS THAN 20 FEET HAVE ONE STRUT	080780	0000
1560	IF(STRUT.LT.BXWTSTRT/15.) STRUT=BXWTSTRT/15.	080790	0000
C	THERE ARE TWO WALERS FOR EVERY STRUT AND A MINIMUM OF TWO WALERS	080800	0000
C	CONNECTING DECKED SOLDIER PILES IN ROCK	080810	0000
	IF(IDECK.EQ.1.AND.DROCK.LT.DTRNCH.AND.WALE.LT.2.*WTWALE+26.)	080820	0000
	1 WALE=2.*WTWALE+26.	080830	0000
	IF(WALE.LT.2.*WTWALE) WALE=2.*WTWALE	080840	0000

(Continued)

COSTEN Listing (Continued)

C	NO STRUTS IF COMPLETELY SUPPORTED BY ANCHORS	080850	0000
	IF(IBRACE.EQ.2) STRUT=0	080860	0000
C	NO WALES FOR SLURRY WALL	080870	0000
	IF(ISUPPT.EQ.6) WALE=0	080880	0000
C	NO COSTS OF WALES AND STRUTS FOR SLURRY WALL SUPPORTED BY ANCHORS	080890	0000
	IF(ISUPPT.EQ.6 .AND. IBRACE.EQ.2) GO TO 1570	080900	0000
	UCL=UCL+45.+1.3*SQRT(WALE+STRUT)	080910	0000
	UCE=UCE+15.+0.45*SQRT(WALE+STRUT)	080920	0000
	UCM=UCM+0.095*WALE+0.2*STRUT	080930	0000
CCC	-----	080940	0000
C	ADD COST OF SOLDIER PILES	080950	0000
CCC	-----	080960	0000
1570	IF(ISUPPT.EQ.6) GO TO 1605	080970	0000
	IF(DROCK.LT.DTRNCH) GO TO 1580	080980	0000
	SPLT=DTRNCH+10.	080990	0000
	GO TO 1600	081000	0000
1580	SPLT=DROCK+10.	081010	0000
1600	IF(IDECK.EQ.0) SPDLT=SPLT	081020	0000
	IF(IDECK.EQ.0) WTSPD=WTSP	081030	0000
	GO TO 1610	081040	0000
C	SOLDIER PILES EMBEDDED IN SLURRY WALL	081050	0000
1605	SPLT=DSLURY	081060	0000
	SPDLT=DSLURY	081070	0000
	WTSP=13	081080	0000
	WTSPD=13	081090	0000
1610	PILE=((2.*SPLT*WTSP+SPDLT*WTSPD)*2./15.	081100	0000
	DWTAUG=SQRT(6. *(2.*WTSP*SPLT+WTSPD*SPDLT)/(2.*SPLT+SPDLT))	081110	0000
	SPLTAU=(2.*SPLT+SPDLT)/3.	081120	0000
	UCL=UCL+(0.009*(DWTAUG+7.)*2-0.2)*0.4*SPLTAU*AR/HOURS	081130	0000
	UCE=UCE+0.02*DWTAUG*SPLTAU*AR/HOURS	081140	0000
	UCM=UCM+0.012*DWTAUG*SPLTAU+0.1*PILE	081150	0000
CCC	-----	081160	0000
C	ADD COST OF LAGGING	081170	0000
CCC	-----	081180	0000
C	NO LAGGING FOR SLURRY WALL	081190	0000
	IF(ISUPPT.EQ.6) GO TO 1710	081200	0000
	IF(DROCK.LT.DTRNCH) GO TO 1660	081210	0000
	IF(DTRNCH.GT.25.) GO TO 1640	081220	0000
	BL=DTRNCH*3.*2./1000.	081230	0000
	GO TO 1700	081240	0000
1640	BL=(25.*3.+(DTRNCH-25.)*4.)*2./1000.	081250	0000
	GO TO 1700	081260	0000
1660	IF(DROCK.GT.25.) GO TO 1680	081270	0000

(Continued)

COSTUN Listing (Continued)

	BL=DROCK*3.32./1000.	081280	0000
	GO TO 1700	081290	0000
1690	BL=(25.*3.+(DROCK-25.)*4)*2./1000.	081300	0000
1700	UCL=UCL+53.*AR*BL/HOURS/0.6	081310	0000
	UCE=UCE+1.4	081320	0000
	UCH=UCH+20.*BL	081330	0000
C	-----	081340	0000
C	ADD COST OF TIEBACK ANCHORS	081350	0000
C	-----	081360	0000
	NO TIEBACK ANCHORS IF COMPLETELY SUPPORTED BY STRUTS	081370	0000
C	1710 IF(IBRACE.EQ.1) GO TO 1750	081380	0000
	IF(DROCK.LT.DTRNCH) GO TO 1720	081390	0000
	ANCHLT=0.3*DTRNCH+20.	081400	0000
	DSOIL=DTRNCH	081410	0000
C	Y1=PORTION SUPPORTED BY TIEBACK ANCHORS	081420	0000
	Y1=1	081430	0000
	IF(IBRACE.EQ.3) Y1=TOTBOX/DTRNCH	081440	0000
	GO TO 1740	081450	0000
1720	ANCHLT=0.3*DROCK+20.	081460	0000
	DSOIL=DROCK	081470	0000
C	Y1=PORTION SUPPORTED BY ANCHORS	081480	0000
	IF(IBRACE.EQ.3 .AND. DROCK.LT.DROOF) Y1=1	081490	0000
	IF(IBRACE.EQ.3 .AND. DROCK.GT.DROOF) Y1=(DROCK-DROOF)/DROCK	081500	0000
1740	ANCHDI=SQR(TANCH/2.67)	081510	0000
	GRTAKE=1.88*DSOIL	081520	0000
	UBF=(ANCHLT-20.)*0.785*(1-(ANCHDI/12.)*2)/27.*0.04*DSOIL	081530	0000
	UCLAN=3.*ANCHLT*DSOIL *AR/HOURS/(10.-80./ANCHLT)*Y1	081540	0000
	IF(UCLAN.LT.75.) UCLAN=75	081550	0000
	UCEAN=0.7*ANCHLT*DSOIL *AR/HOURS/(10.-80./ANCHLT)*Y1	081560	0000
	IF(UCEAN.LT.17.5) UCEAN=17.5	081570	0000
	UCHAN=(ANCHDI**2*(0.8-0.003*ANCHLT)*0.04*ANCHLT*DSOIL +80.*GRTAKE	081580	0000
1	/27.+6.75*UBF)*Y1	081590	0000
	UCL=UCL+UCLAN	081600	0000
	UCE=UCE+UCEAN	081610	0000
	UCH=UCH+UCHAN	081620	0000
C	-----	081630	0000
C	ADD COST OF ROCK BOLTS	081640	0000
C	-----	081650	0000
1750	IF(DROCK.LT.DTRNCH) GO TO 1760	081660	0000
	GO TO 1800	081670	0000
1760	ANCHLT=0.25*(DTRNCH-DROCK)+250./RQD	081680	0000
	UCLRB=110.*ANCHLT*(DTRNCH-DROCK)*AR/HOURS/(1.2+130./((110.-RQD))*2	081690	0000
1	/(50.-0.25*ANCHLT)	081700	0000
	IF(UCLRB.LT.54.) UCLRB=54.	081710	0000
	UCERB=20.*ANCHLT*(DTRNCH-DROCK)*AR/HOURS/(1.2+130./((110.-RQD))*2	081720	0000
1	/(50.-0.25*ANCHLT)	081730	0000
	IF(UCERB.LT.10.) UCERB=10	081740	0000
	UCHRB=1.5*ANCHLT*(DTRNCH-DROCK)/(1.2+130./((110.-RQD))*2	081750	0000
	UCL=UCL+UCLRB	081760	0000
	UCE=UCE+UCERB	081770	0000
	UCH=UCH+UCHRB	081780	0000
1800	IF(NEX.EQ.7) GO TO 300	081790	0000
C	-----	081800	0000
C	DECKING	081810	0000
C	-----	081820	0000
	IS DECKING REQUIRED	081830	0000
	IF(IDECK.EQ.1) GO TO 1820	081840	0000
	GO TO 300	081850	0000

(Continued)

COSTUN Listing (Continued)

C	ADD COST OF TIMBER	081860	0000
1820	UCL=UCL+0.072*BE*AR/HOURS	081870	0000
	UCE=UCE+0.009*BE*AR/HOURS	081880	0000
	UCH=UCH+0.18*BE	081890	0000
C	ADD COST OF GIRDERS AND STRINGERS	081900	0000
	UCL=UCL+15.+(5.3*BE+520.)*X2/40000.	081910	0000
	UCE=UCE+5.5+7.2*(BE+100.)*X2/10000.	081920	0000
	UCH=UCH+0.16*(5.3*BE+30.)	081930	0000
	GO TO 300	081940	0000
	END	081950	0000
	SUBROUTINE LINING1(CLL,CEL,CML,CLFU,CEFU,CMFU,ITYPE,LINING,RQD,PEX	081960	0000
	1,UEB,TL,BOB,BOB40,BF,Y,DM,BOB60,ISHAPE,BE,UCLT,UCET,MTM,	081970	0000
	BUCLMH,UCEMH,SFA,NOFORM,AR,NSTYP,P5OIL,PWATER,UL,SFP,	081980	0000
	3FORMAN,HOURS,CFLCA,CFLWUK,CFEWUK)	081990	0000
	-----	082000	0000
	LINING CALCULATES THE LINING COSTS AND THE FORMWORK COST FOR A	082010	0000
	TUNNEL OR SHAFT SEGMENT	082020	0000
	-----	082030	0000
	IF(NSTYP.EQ.3) GO TO 910	082040	0000
	***** ROCK OR SOFT GROUND *****	082050	0000
	II IS A FLOW INDICATOR	082060	0000
	-----	082070	0000
	-----	082080	0000
	IS SEGMENT LINED	082090	0000
	IF(LINING.GT.0) GO TO 37	082100	0000
	SEGMENT IS UNLINED --- SET ALL COSTS TO ZERO	082110	0000
C	CLL=0.0	082120	0000
	CEL=0.0	082130	0000
	CML=0.0	082140	0000
2	CLFU=0.0	082150	0000
	CEFU=0.0	082160	0000
	CMFU=0.0	082170	0000
	RETURN	082180	0000
	-----	082190	0000
	-----	082200	0000
	-----	082210	0000
	-----	082220	0000
	-----	082230	0000
	RATIO OF REINFORCEMENT TO CONCRETE BY VOLUME	082240	0000
	-----	082250	0000
	SET MINIMUM STEEL REQUIREMENTS	082260	0000
37	IF(NSTYP.EQ.1) RSTMIN=0.005	082270	0000
	IF(NSTYP.EQ.2) RSTMIN=0.01	082280	0000
	IF(ITYPE.EQ.2) GO TO 49	082290	0000
C	TUNNEL SEGMENT	082300	0000
	GO TO(41,42,45),ISHAPE	082310	0000
C	CIRCLE	082320	0000
41	RST=RSTMIN	082330	0000
	GO TO 4	082340	0000
C	HORSESHOE	082350	0000
42	RST=0.014-7.3E-8*PWATER	082360	0000
	IF(LINING.EQ.1) PMINT=195000/BF*X1.7	082370	0000
	IF(LINING.EQ.2) PMINT=36500/BF*X1.6	082380	0000
44	RSTMT=0.014-7.3E-8*PMINT	082390	0000
	GO TO 48	082400	0000
C	BASKETHANDLE	082410	0000
45	RST=0.014-6.6E-8*PWATER	082420	0000
	IF(LINING.EQ.1) PMINT=220000/BF*X1.9	082430	0000

(Continued)

48	IF(LINING.EQ.2) PMINT=56000/BF**1.8	082440	0000
47	RSTMT=0.014-6.6E-8*PMINT	082450	0000
	GO TO 48	082460	0000
C	SHAFT SEGMENT	082470	0000
C	IS IT CIRCULAR SHAPE	082480	0000
49	IF(ISHAPE.EQ.1) GO TO 41	082490	0000
	RST=0.015-6.25E-8*PWATER	082500	0000
	IF(LINING.EQ.1) PMINT=175000/BF**1.9	082510	0000
50	IF(LINING.EQ.2) PMINT=31000/BF**1.8	082520	0000
51	RSTMT=0.015-6.25E-8*PMINT	082530	0000
48	IF(PWATER.LE.PMINT) RST=RST*MIN+(RSTMT-RST*MIN)*PWATER/PMINT	082540	0000
	IF(RST.LT.RST*MIN) RST=RST*MIN	082550	0000
C	-----	082560	0000
C	IS IT A SOFT GROUND TUNNEL OR SHAFT	082570	0000
4	IF(NSTYP.EQ.2) GO TO 40	082580	0000
C	ROCK TUNNELS OR SHAFTS	082590	0000
C	CHECK RQD	082600	0000
5	IF(RQD.LE.40.) GO TO 40	082610	0000
	IF(RQD.GE.60.) GO TO 20	082620	0000
C	RQD IS BETWEEN 40 AND 60 INTERPOLATION OF COSTS IS NECESSARY.	082630	0000
C	COST WILL BE COMPUTED FOR RQD=40 AND THEN FOR RQD=60 BEFORE	082640	0000
C	INTERPOLATING TO OBTAIN COSTS AT ACTUAL RQD.	082650	0000
10	II=1	082660	0000
C	STORE THE CORRECT VALUES OF RQD AND BOB	082670	0000
	RQD=RQD	082680	0000
	BOB=BOB	082690	0000
C	ESTABLISH FICTITIOUS VALUES OF RQD AND SIZE FOR INTERPOLATION USE	082700	0000
	RQD=40.	082710	0000
	BOB=BOB40	082720	0000
	GO TO 55	082730	0000
C	RQD .GE. 60	082740	0000
20	II=4	082750	0000
30	F=1.	082760	0000
	GO TO (200,300),LINING	082770	0000
C	RQD .LE. 40	082780	0000
40	II=4.	082790	0000
55	IF(LINING.EQ.1) GO TO 200	082800	0000
C	IS THIS A SOFT GROUND TUNNEL OR SHAFT	082810	0000
	IF(NSTYP.EQ.2) GO TO 300	082820	0000
	S=0.05*RQD+1.25	082830	0000
C	TL IS STORED IN FEET	082840	0000
59	IF(TL.LT.WEB) GO TO 70	082850	0000
C	F IS A FACTOR FOR INCREASING SHOTCRETE VOLUME OVER STEEL SETS	082860	0000
60	F=1.	082870	0000
	GO TO 300	082880	0000
70	F=(S+WEB/4.)/S	082890	0000
	GO TO 300	082900	0000
C	-----	082910	0000
C	*****	082920	0000
C	CONCRETE LINING	082930	0000
C	-----	082940	0000
200	UL=SFA/27.*(BOB**2-BF**2)	082950	0000
	ULREIN=SFA/27.*(BE**2.-BF**2.)	082960	0000
	IF(NSTYP.EQ.2) UL=4./27.*SFA*TL*(BF+TL)	082970	0000
	IF(NSTYP.EQ.2) ULREIN=UL	082980	0000
	UREIN=491.*RST*ULREIN*27.	082990	0000
	GO TO(220,260),ITYPE	083000	0000
220	IF(NSTYP.EQ.2) GO TO 230	083010	0000

(Continued)

(CONTINUED LISTING (Continued))

C	-----	083020	0000
C	UNIT COST OF LINING MATERIAL TRANSPORT IN TUNNELS ONLY	083030	0000
	GO TO (221,225,223,221),MTM	083040	0000
C	TRUCK TRANSPORT, Z=TRUCK VOLUME/4	083050	0000
221	IF(ISHAPE.LE.2) Z=5.-0.001*(70.-BE)**2	083060	0000
	IF(ISHAPE.EQ.3) Z=4.5-(BE-50.)*X4/44000.	083070	0000
	TRUCKS=(0.28*DM+0.48)*UL/2	083080	0000
	IF(TRUCKS.LT.1.0) TRUCKS=1.	083090	0000
	UCLT=7.7*TRUCKS+7.1	083100	0000
	UCET=(1.5+3.1*Z)*TRUCKS	083110	0000
	GO TO 226	083120	0000
C	RAIL TRANSPORT	083130	0000
223	CARS=(0.42*DM+1.5)*UL	083140	0000
	IF(CARS.LT.1.0) CARS=1.0	083150	0000
	ENGINE=CARS/10.	083160	0000
	IF(ENGINE.LT.1.0) ENGINE=1.	083170	0000
	UCLT=15.*ENGINE+21.*DM**0.82	083180	0000
	UCET=5.8*ENGINE+CARS+1.4*DM	083190	0000
	GO TO 226	083200	0000
225	CONTINUE	083210	0000
C	CONVEYOR -- UCET AND UCLT WERE COMPUTED IN SUBROUTINE CMTAH	083220	0000
226	AL=3.*HOURS	083230	0000
	GO TO 240	083240	0000
230	UCLT=0	083250	0000
	UCET=0	083260	0000
	UCEMH=0	083270	0000
	AL=AR	083280	0000
C	UNIT COSTS OF LINING IN TUNNEL	083290	0000
240	UCL=(0.0018*(UL*AL/HOURS+160.))*2-12.+UCLT)*XCFLCA	083300	0000
	UCE=5.+0.3*UL*AL/HOURS+UCET+UCEMH	083310	0000
	UCM=13.+0.15*UREIN/UL	083320	0000
	GO TO 400	083330	0000
C	-----	083340	0000
C	UNIT COST OF SHAFT LINING	083350	0000
260	UCL= 25.+3.0*UL+UCLMH	083360	0000
	UCE=7.+0.40*UL+UCEMH	083370	0000
	UCM=13.+0.15*UREIN/UL	083380	0000
	AL=2.*HOURS	083390	0000
	GO TO 400	083400	0000
C	*****	083410	0000
C	*****	083420	0000
C	SHOTCRETE LINING	083430	0000
300	UL=4.*SFA/27.*TL*F*(BOB-TL)	083440	0000
	IF(INSTVP.EQ.2) UL=4./27.*SFA*TL*(BF+TL)	083450	0000
	ULREIN=UL	083460	0000
	AL=AR	083470	0000
	UREIN=491.*RST*ULREIN*27.	083480	0000
C	-----	083490	0000
C	COST OF LINING MATERIAL TRANSPORT IN SHOTCRETED TUNNELS IS	083500	0000
C	INCLUDED IN MUCK TRANSPORT AND HOISTING COSTS.	083510	0000
C	CALCULATE UNIT COSTS OF TUNNEL AND SHAFT LINING	083520	0000
	UCL=(0.035*(UL*AL/HOURS+40.))*2.+10.)*XCFLCA	083530	0000
	IF(ITYPE.EQ.2) UCL=0.035*(UL*AL/HOURS+40.))*2+10.	083540	0000
	UCE=0.004*(UL*AL/HOURS+100.))*2.-23.	083550	0000
	UCM=14.+0.15*UREIN/UL	083560	0000
C	*****	083570	0000
C	*****	083580	0000
400	CONTINUE	083590	0000

(Continued)

COSTUN Listing (Continued)

C	CALCULATE LINING COSTS	083600	0000
	IF(LINING.EQ.2) UCLMH=0.	083610	0000
	IF(ITYPE.EQ.1) CLL=(HOURS*CFLOWK*V*DM)/AL*UCL+HOURS*CFLOWK*UCLMH/AL	083620	0000
	IF(ITYPE.EQ.2) CLL=HOURS*UCL*CFLOWK/AL	083630	0000
	CEL=HOURS*CFEJWK*UCE/AL	083640	0000
	CML=UCL*UCH	083650	0000
C	-----	083660	0000
	IF(II.QE.3) GO TO 525	083670	0000
	IF(II.QE.2) GO TO 500	083680	0000
C	STORE LINING COSTS COMPUTED USING FICTITIOUS RQD=40	083690	0000
	CL40=CLL	083700	0000
	CE40=CEL	083710	0000
	CM40=CML	083720	0000
C	REDEFINE RQD TO A FICTITIOUS VALUE OF 60 FOR SECOND PART OF	083730	0000
C	INTERPOLATION COMPUTATION	083740	0000
	RQD=60	083750	0000
	BOB=BOB60	083760	0000
C	REDEFINE FLOW INDICATOR	083770	0000
	II=II+1	083780	0000
	GO TO 30	083790	0000
C	-----	083800	0000
C	STORE LINING COSTS COMPUTED USING FICTITIOUS RQD=60	083810	0000
C	500 CL60=CLL	083820	0000
	CE60=CEL	083830	0000
	CM60=CML	083840	0000
C	INTERPOLATE BETWEEN RQD OF 40 AND 60 TO OBTAIN LINING COSTS	083850	0000
	CLL=CL40+(RQDD-40.)/20.*(CL60-CL40)	083860	0000
	CEL=CE40+(RQDD-40.)/20.*(CE60-CE40)	083870	0000
	CML=CM40+(RQDD-40.)/20.*(CM60-CM40)	083880	0000
	-----	083890	0000
C	REINSTATE ORIGINAL VALUES OF RQD AND BOB	083900	0000
C	RQD=RQDD	083910	0000
	BOB=BOB	083920	0000
	-----	083930	0000
C	UNIT COST OF FORMWORK EQUALS ZERO FOR SHOTCRETE	083940	0000
C	525 IF(LINING.EQ.2) GO TO 2	083950	0000
	LINING IS CONCRETE. CHECK FOR SUPPRESSED FORMWORK COSTS	083960	0000
C	IF(NOFORM.GT.0) GO TO 2	083970	0000
	IF(ITYPE.EQ.2) GO TO 550	083980	0000
C	UNIT COST OF FORMWORK IN TUNNELS	083990	0000
	UCL=9.*BF*CFLLCA	084000	0000
	IF(ISHAPE.EQ.1) X=2.2	084010	0000
	IF(ISHAPE.EQ.2) X=2.0	084020	0000
	IF(ISHAPE.EQ.3) X=1.6	084030	0000
	UCE=15.*X*BF	084040	0000
	UCH=0.18*BF	084050	0000
	AL=3.*HOURS	084060	0000
	IF(NSTYP.EQ.2) AL=AR	084070	0000
	GO TO 700	084080	0000
C	UNIT COST OF FORMWORK IN SHAFTS	084090	0000
C	550 IF(ISHAPE.EQ.1) SFP=3.14	084100	0000
	IF(ISHAPE.EQ.2) SFP=4.	084110	0000
	UCL=25.*4.*BF	084120	0000
	UCE=(10.+1.5*BF)*SFP/3.14	084130	0000
	UCH=0.72*BF	084140	0000
	AL=8.*HOURS	084150	0000
	GO TO 700	084160	0000
		084170	0000

(Continued)

COSTUN Listing (Continued)

C	COMPUTE FORMWORK COSTS	084180	0000
700	CLFU=(HOURS*CFLOWK+VSDM)*UCL/AL	084190	0000
	CEFU=HOURS*CFEWWK*UCE/AL	084200	0000
	CMFU=UCH	084210	0000
	GO TO 1000	084220	0000
C	***** CUT AND COVER *****	084230	0000
910	IF(ITYPE.EQ.2) GO TO 940	084240	0000
C	TUNNEL	084250	0000
	IF(LINING.EQ.3) GO TO 930	084260	0000
C	-----	084270	0000
	CIP BOX	084280	0000
	UCL=480.-0.075*(70.-UL)*2	084290	0000
	UCE=55.-0.008*(65.-UL)*2	084300	0000
	UCH=26.*UL	084310	0000
	HOURCR=UL *AR/(110.-0.03*(UL -60.))*2	084320	0000
	IF(HOURCR.LT.8.) HOURCR=8	084330	0000
	CLL=UCL*HOURCR/AR*CFLOWK	084340	0000
	CEL=UCE*HOURCR/AR*CFEWWK	084350	0000
	CMF=UCH	084360	0000
	HOURCR=FORMAR*AR/(620.-0.004*(FORMAR-400.))*2	084370	0000
	IF(HOURCR.LT.8.) HOURCR=8	084380	0000
	CLFU=(100.+0.85*FORMAR)*HOURCR/AR*CFLOWK	084390	0000
	CEFU=(8.+(FORMAR+100.))*2/4500.)*HOURCR/AR*CFEWWK	084400	0000
	CMFU=0.35*FORMAR	084410	0000
	RETURN	084420	0000
C	-----	084430	0000
	PRECAST CONCRETE BOX	084440	0000
930	UCL=(0.07*(UL +10.))*2-7.)*50./UL	084450	0000
	UCE=(0.007*(UL +80.))*2-45.)*50./UL	084460	0000
	UCH=104.*UL	084470	0000
	HOURCR=UL*AR/50.	084480	0000
	IF(HOURCR.LT.8.) HOURCR=8	084490	0000
	CLL=UCL*HOURCR/AR*CFLOWK	084500	0000
	CEL=UCE*HOURCR/AR*CFEWWK	084510	0000
	CMF=UCH	084520	0000
	GO TO 2	084530	0000
C	-----	084540	0000
	SHAFT	084550	0000
940	IF(ISHAPE.EQ.2) GO TO 945	084560	0000
	SFP=3.14	084570	0000
	GO TO 950	084580	0000
945	SFP=4	084590	0000
950	UL=(BF+TL)*TL*SFP/27.	084600	0000
	UCL= 0.07*(UL +10.))*2-7.	084610	0000
	UCE= 0.007*(UL +80.))*2-45.	084620	0000
	UCH=104.*UL	084630	0000
	CLL=UCL*CFLOWK	084640	0000
	CEL=UCE*CFEWWK	084650	0000
	CMF=UCH	084660	0000
	GO TO 2	084670	0000
1000	RETURN	084680	0000
	END	084690	0000
	SUBROUTINE CGROUT(CLG,CEG,CMG,ITYPE,GI,ISHAPE,BE,AR,RS,NSTYP,	084700	0000
	INSTAB, DTUN,MH,HOURS,CFLOWK,CFEWWK,SSEGL,PERM,SFP,DIG,TIMEG)	084710	0000
C	-----	084720	0000
	-----	084730	0000
	-----	084740	0000
C	CGROUT CALCULATES THE COST OF GROUTING IN A TUNNEL OR SHAFT	084750	0000

(Continued)

COSTUN Listing (Continued)

C	SEGMENT	084760	0000
C	-----	084770	0000
C	-----	084780	0000
C	-----	084790	0000
C	IF(NSTYP.EQ.2) GO TO 500	084800	0000
C	IF(NSTYP.EQ.3) GO TO 650	084810	0000
C	***** ROCK *****	084820	0000
C	IF(ITYPE.EQ.2) GO TO 300	084830	0000
C	-----	084840	0000
C	TUNNEL	084850	0000
C	IF(QI.GE.100.) GO TO 150	084860	0000
C	COST OF GROUTING EQUALS ZERO	084870	0000
100	CLG=0	084880	0000
	CEG=0	084890	0000
	CNG=0	084900	0000
	RETURN	084910	0000
150	IF(ISHAPE.EQ.1) SFP=3.14	084920	0000
	IF(ISHAPE.EQ.2) SFP=3.57	084930	0000
	IF(ISHAPE.EQ.3) SFP=2.66	084940	0000
	GT=0.005*SFP*BE*(1.+0.1*GI)	084950	0000
	GO TO 400	084960	0000
C	-----	084970	0000
C	SHAFT	084980	0000
C	IF(QI.LT.1.) GO TO 100	084990	0000
C	SHAFT IS WET,GROUTING REQUIRED	085000	0000
	SFP=3.14	085010	0000
	GT=0.01*SFP*BE	085020	0000
400	CONTINUE	085030	0000
	HL=SFP*BE/4.	085040	0000
	UCL=0	085050	0000
	UCE=33.-0.015*(BE-46.)*X2	085060	0000
	UCN=1.25*GT+RS*HL/200000.+0.075*HL-0.05*(BE-46.)*X2/AR+100./AR	085070	0000
	GO TO 1000	085080	0000
C	-----	085090	0000
C	***** SOFT GROUND *****	085100	0000
C	IS IT A SHAFT	085110	0000
C	IF(ITYPE.EQ.2) GO TO 640	085120	0000
C	-----	085130	0000
C	TUNNEL	085140	0000
C	STABILIZED BY GROUND INJECTIONS	085150	0000
	IF(MSTAB.EQ.3) GO TO 550	085160	0000
	GO TO 650	085170	0000
C	IS TUNNEL CROWN DEEPER THAN 50 FT	085180	0000
550	IF(ISHAPE.LE.2.AND. DTUN-BE/2.GT.50.) GO TO 600	085190	0000
	IF(ISHAPE.EQ.3 .AND. DTUN-BE/4.GT.50.) GO TO 600	085200	0000
C	GROUTING FROM GROUND SURFACE	085210	0000
	TIMEG=0.6+DTUN/20.+BE/40.	085220	0000
	IF(ISHAPE.EQ.3) TIMEG=0.6+DTUN/20.+BE/80.	085230	0000
	UCL=79.*(BE+10.)/25.*TIMEG*AR/HOURS	085240	0000
	UCE=15.*(BE+10.)/25.*TIMEG*AR/HOURS	085250	0000
	UCN=3.*TIMEG*(BE+10.)/25.+0.25*(BE+10.)*X2*(0.55+0.15*XALOG10(SQRT	085260	0000
	1(10.*ABS(PERM))))/(1.55+0.15*XALOG10(SQRT(10.*ABS(PERM))))	085270	0000
	IF(ISHAPE.EQ.3) UCN=3.*TIMEG*(BE+10.)/25.+0.25*(BE+10.)*X(0.5*BE+	085280	0000
	110.)*X(0.55+0.15*XALOG10(SQRT(10.*ABS(PERM))))/(1.55+0.15*XALOG10(SQ	085290	0000
	RT(10.*ABS(PERM))))	085300	0000
	GO TO 1000	085310	0000
C	GROUTING FROM EXCAVATION FACE	085320	0000
600	UCL=0	085330	0000

(Continued)

COSTUN Listing (Continued)

	UCE=3.4*BE	085340 0000
	UCH=0.14*BE+0.8*(0.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))/	085350 0000
	1*(1.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))*BE*SFP	085360 0000
	GO TO 1000	085370 0000
C	-----	085380 0000
C	SHAFT	085390 0000
C	STABILIZED BY GROUND INJECTIONS	085400 0000
640	IF(NSTAB.EQ.3) GO TO 700	085410 0000
650	CLG=0.	085420 0000
	CEG=0.	085430 0000
	CMG=0.	085440 0000
	RETURN	085450 0000
C	IS SEGMENT MIDPOINT DEEPER THAN 200 FT	085460 0000
700	IF(MH.GT.200.) GO TO 600	085470 0000
C	GROUTING FROM GROUND SURFACE	085480 0000
	UCL=79.*TIMEG*(BE+5.)*SFP/5./DTG*AR/HOURS	085490 0000
	UCE=15.*TIMEG*(BE+5.)*SFP/5./DTG*AR/HOURS	085500 0000
	UCH=0.6*TIMEG*(BE+5.)*SFP/DTG+0.64*(0.55+0.15*ALOG10(SQRT(10.*ABS	085510 0000
	1(PERM))))*(BE+5.)*SFP/(1.55+0.15*ALOG10(SQRT(10.*ABS(PERM))))	085520 0000
C	-----	085530 0000
C	COST OF GROUTING	085540 0000
1000	CLG=UCL*HOURS*CFLWUK/AR	085550 0000
	CEG=UCE*HOURS*CFEUK/AR	085560 0000
	CMG=UCH	085570 0000
	RETURN	085580 0000
	END	085590 0000
	SUBROUTINE CPUMP(CLP,CEP,CMF,NSTYP,FLOW,PH,PIPL,AR,	085600 0000
	1ITYPE,ELSURF,ELBOTN,DAYS,LINING,PUMPTM,NEX,DTRNCH,DROCK,FLOWL,	085610 0000
	2WELLS,RL,TIMEDW,ISUPPT,ELWATR,ELNPS,IWATER,CFLWUK,CFEUK)	085620 0000
C	-----	085630 0000
C	CPUMP CALCULATES THE PUMPING COSTS	085640 0000
C	PUMPING TIME COMPUTED IN COSTSF IS FOR SOFT GROUND SHAFT ONLY	085650 0000
C	ASSUME PUMPING 24 HR A DAY , 7 DAYS A WEEK OPERATION	085660 0000
C	-----	085670 0000
C	-----	085680 0000
C	IF(NSTYP.EQ.3) GO TO 300	085690 0000
C	ROCK OR SOFT GROUND	085700 0000
C	IF(NSTYP.EQ.2) GO TO 100	085710 0000
C	-----	085720 0000
C	ROCK	085730 0000
	-----	085740 0000
		085750 0000

(Continued)

COSTUN Listing (Continued)

C	SET COSTS=0	085760	0000
	UCL=0.	085770	0000
	UCE=0.	085780	0000
	UCR=0.	085790	0000
	GO TO 800	085800	0000
C	-----	085810	0000
	DEEP WELL PUMPING	085820	0000
C	-----	085830	0000
	SOFT GROUND	085840	0000
C	100 IF(ITYPE.EQ.2) GO TO 250	085850	0000
C	-----	085860	0000
	TUNNEL	085870	0000
	WELLN=ELSURF-ELBOTM	085880	0000
C	PROVIDE 5 DAYS PUMPING AHEAD OF EXCAVATION TO REVERSE FLOW	085890	0000
C	PROVIDE 50 FT FINISHED LINING PAST PUMP BEFORE STOPPING ITEM	085900	0000
	IF(ISUPP.LE.3) GO TO 180	085910	0000
C	STEEL RIBS WITH LINING	085920	0000
C	PROVIDE THE GREATER OF TIME TO FINISH 50 FT LINING AHEAD OF PUMP,	085930	0000
C	OR 30 CALENDAR DAYS FOR CURING OF CONCRETE	085940	0000
C	SHOTCRETE IS PLACED UP TO THE FACE. CONCRETE IS KEPT 150 FT	085950	0000
C	BEHIND FACE.	085960	0000
	IF(50./AR*7./DAYS.GE.30.) GO TO 150	085970	0000
C	-----	085980	0000
	PUMPING TIME CONTROLLED BY CURING TIME	085990	0000
C	CONCRETE	086000	0000
	IF(LINING.EQ.1) PUMPTM=35.+150./AR*7./DAYS	086010	0000
C	SHOTCRETE	086020	0000
	IF(LINING.EQ.2) PUMPTM=35.	086030	0000
	GO TO 450	086040	0000
C	-----	086050	0000
	PUMPING TIME CONTROLLED BY PLACING RATE OF LINING	086060	0000
C	CONCRETE	086070	0000
C	150 IF(LINING.EQ.1) PUMPTM=5.+200./AR*7./DAYS	086080	0000
C	SHOTCRETE	086090	0000
	IF(LINING.EQ.2) PUMPTM=5.+50./AR*7./DAYS	086100	0000
	GO TO 450	086110	0000
C	SEGMENTED SUPPORT	086120	0000
C	180 PUMPTM=5.+50./AR*7./DAYS	086130	0000
	GO TO 450	086140	0000
C	-----	086150	0000
	SHAFT	086160	0000
C	250 IF(ELWATR.LT.ELNPB) GO TO 950	086170	0000

(Continued)

COSTUN Listing (Continued)

C	PUMPING TIME DETERMINED IN COSTSF	086180	0000
C	WELLS=3	086190	0000
C	NO WELLS IF FLOW=0	086200	0000
C	IF(FLOW.LT.0.0001) WELLS=0	086210	0000
C	CONSIDER 1 FT LENGTH OF SHAFT	086220	0000
	WELLN=1	086230	0000
	GO TO 450	086240	0000
C	-----	086250	0000
C	CUT-AND-COVER	086260	0000
300	IF(ITYPE.EQ.2) GO TO 950	086270	0000
C	TUNNEL	086280	0000
	IF(ELWATR.LT.ELSURF-DTRNCH) GO TO 950	086290	0000
	IF(IWATER.EQ.0) GO TO 900	086300	0000
C	IS IT SOLDIER PILE WITH LAGGING	086310	0000
	IF(ISUPPT.EQ.5) GO TO 350	086320	0000
	IF(DROCK.LT.DTRNCH .AND. ELWATR.LT.ELSURF-DROCK) GO TO 950	086330	0000
	GO TO 400	086340	0000
C	IS ROCK LINE ABOVE TRENCH BOTTOM	086350	0000
350	IF(DROCK.LT.DTRNCH) GO TO 900	086360	0000
400	PUMPTM=(1./AR+(TIMEDW+10.)/RL)*7./DAYS	086370	0000
	IF(LINING.EQ.1) PUMPTM=(1./AR+(TIMEDW+40.)/RL)*7./DAYS	086380	0000
	WELLN=DTRNCH	086390	0000
	IF(WELLN.GT.DROCK) WELLN=DROCK	086400	0000
450	PIPED=0.5*FLOWL**0.4	086410	0000
	IF(PIPED.LT.1.) PIPED=1	086420	0000
C	SETUP COST OF DEEP WELLS	086430	0000
	UCL=(0.4*PIPED+3.2)*WELLN*WELLS*AR/24.*DAYS/7.*CFWUK/1.12	086440	0000
	UCE=(0.15*PIPED+1.)*WELLN*WELLS*AR/24.*DAYS/7.*CFWUK/0.715	086450	0000
	UCH=(0.75*PIPED+3.)*WELLN*WELLS*AR/24.*DAYS/7.	086460	0000
C	OPERATING COST OF DEEP WELLS	086470	0000
	UCL=UCL+0.85*WELLS*PUMPTM*AR*DAYS/7.	086480	0000
	UCE=UCE+0.000265*FLOWL*PH*(0.0026+7./(2000.+0.000265*FLOWL*PH))*	086490	0000
	1*WELLS*PUMPTM*AR*DAYS/7.	086500	0000
	UCH=UCH+5.*PH*FLOWL/1000000.*WELLS*PUMPTM*AR*DAYS/7.	086510	0000
C	SETUP	086520	0000
C	IS IT CUT-AND-COVER	086530	0000
	IF(NSTYP.EQ.3) GO TO 1000	086540	0000
C	SOFT GROUND	086550	0000
	IF(ITYPE.EQ.2) GO TO 1000	086560	0000
C	-----	086570	0000
C	PUMPING FROM TUNNEL	086580	0000
C	-----	086590	0000

(Continued)

COSTUN Listing (Continued)

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C -----
800 IF(FLOW.GT.0.) GO TO 850
C NO COST IF FLOW IS ZERO
GO TO 1000
850 IF(PH.LE.0.) GO TO 1000
UCL=UCL+5.+11.*PH/3000.+0.003*PIPL
UCE=UCE+(0.25+PH/2000.)*FLOW/500.
UCM=UCM+5.*PH/1000.*FLOW/1000.
GO TO 1000
C -----
C SUMP PUMPING
C -----
900 PUMPTM=(1./AR+10./RL)*7./DAYS
IF(LINING.EQ.1) PUMPTM=(1./AR+40./RL)*7./DAYS
UCL=5.*PUMPTM/500.*AR*7./DAYS
UCE=0.4*PUMPTM/500.*AR*7./DAYS
UCM=(0.15+0.000044*PH*FLOW)*PUMPTM/500.*AR*7./DAYS
GO TO 1000
C SHAFT
950 CLP=0.
CEP=0.
CMP=0.
RETURN
C -----
C CALCULATE PUMPING COSTS
1000 CLP=UCL*24./AR*7./DAYS*1.12
CEP=UCE*24./AR*7./DAYS*0.715
CMP=UCM*24./AR*7./DAYS
RETURN
END
SUBROUTINE CAIRC(CIAC,CEAC,CMAC,Q,QT,BE,BF,AR,HOURS,NSTYP,MSTAB,
1 ITYPE,AIRPR,SFA,ISHAPE,HH,CAUT,ALOCK,DTC,DTCa,PUMPLT,DM,
2 ALOCKL,UCMCP,CFLWUK,CFEWUK,DAYS,Y,PERM)
C -----
C CAIRC COMPUTES THE COSTS OF VENTILATION, AIR COOLING,
C COMPRESSED AIR, AND AIR LOCKS
C -----
IF(NSTYP.EQ.3) GO TO 400
IF(NSTYP.EQ.1) GO TO 50
D10=SQRT(10.*ABS(PERM))
IF(D10.LT.0.005) D10=0.005
C SHAFT OR TUNNEL
50 IF(ITYPE.EQ.2) GO TO 300
C ***** TUNNELS *****
C CHECK COOLING REQUIREMENT
IF(Q.GT.0.) GO TO 100
C NO COOLING
UCLC=0.
UCLMC=0.
UCEC=0.
UCMC=0.
GO TO 200
C COST OF SETUP AND OPERATION OF COOLING PLANT
100 IF(ALOCK.GT.0.) UCLMC=QT*ALOCK/48.
IF(ALOCK.LT.0.) UCLMC=QT*(1.-ALOCK)/48.
UCLC=5.20
UCEC=0.000013*QT
UCMC=0.000008*Q
086590 0000
086600 0000
086610 0000
086620 0000
086630 0000
086640 0000
086650 0000
086660 0000
086670 0000
086680 0000
086690 0000
086700 0000
086710 0000
086720 0000
086730 0000
086740 0000
086750 0000
086760 0000
086770 0000
086780 0000
086790 0000
086800 0000
086810 0000
086820 0000
086830 0000
086840 0000
086850 0000
086860 0000
086870 0000
086880 0000
086890 0000
086900 0000
086910 0000
086920 0000
086930 0000
086940 0000
086950 0000
086960 0000
086970 0000
086980 0000
086990 0000
087000 0000
087010 0000
087020 0000
087030 0000
087040 0000
087050 0000
087060 0000
087070 0000
087080 0000
087090 0000
087100 0000
087110 0000
087120 0000
087130 0000
087140 0000
087150 0000
087160 0000

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(Continued)

COSTUN Listing (Continued)

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C -----
200 IF(MSTAB.NE.1) GO TO 60
C COMPRESSED AIR
CAU=(28.5+10.*XALOG10(D10))*SFAXBEXX2
ALOKA=ABS(ALOCK)
UCLCA=16.4
C COSTS OF AIR LOCK AND SETUP
UCLLKA=20.4
UCLLCK=(38000.+3.*XHH)*X(1.+0.25*(ALOKA-1.))
UCELOK=(10000.+0.8*XHH)*X(1.+0.25*(ALOKA-1.))
ALOCKD=BF
IF(ISHAPE.EQ.3) ALOCKD=0.5*BF
IF(ALOCKD.GT.15.) ALOCKD=15.
IF(ALOCKL.LT.30.) ALOCKL=30.
NALOCK=16.*ALOCKD*(ALOCKL+ALOCKD)
UBULK=5.*(SFAXBFX2-0.785*ALOCKDX2)/27.
UCHLCK=(1200.+0.1*XHH)*X(1.+0.25*(ALOKA-1.))+140.*UBULK*ALOKA
C COST OF COMPRESSED AIR PLANT, SETUP AND OPERATION
UCLMCA=0.075*(30000.+14.4*CAUT)*ALOKA
UCECA=2.3+0.0011*CAUT
UCMCA=0.003*CAUX*((AIRPR+14.7)/14.7+0.000123*XPUMPLT)*X0.242-1.)
CLAC=(UCLLKA*HOURS/AR+UCLMC/DTC+(UCLMCA+UCLLCK)/DTC)*XCFLUWK
1 +(UCLCA+UCLC)*X24./AR*X7./DAYS*X1.12
CEAC=(UCEC+UCECA)*X24./AR*X7./DAYS*X0.715+UCELOK/DTC*XCFLUWK
CMAC=(UCHC+UCHCA)*X24./AR*X7./DAYS+UCMCP+UCMLCK/DTC
1 +0.000015*NALOCK*HOURS/AR
GO TO 500
C -----
C CALCULATE UNIT COSTS OF VENTILATION
60 UCLV=3.*XDM
UCEV=0.5+0.625*SFAXBEXX2/1000.
UCMV=3.3*SFAXBEXX2*XDM/1000.
UCMDFU=3.*SFAXBEXX2/200.
CLAC=UCLV*(HOURS*XCFLUWK+0.5*XV*XDM)/AR
IF(DTC.GT.0.) CLAC=CLAC+(UCLMC/DTC+HOURS*UCLC/AR/4.)*XCFLUWK
CEAC=(UCEV+UCEC*HOURS/AR/4.)*XCFLUWK
CMAC=UCMDFU+HOURS*UCMV/AR+UCMCHOURS/AR/4.
GO TO 500
C ***** SHAFTS *****
C COMPRESSED AIR AND COOLING COSTS
300 IF(NSTYP.EQ.1.OR.MSTAB.NE.1) GO TO 400
CAU=(28.5+10.*XALOG10(D10))*SFAXBEXX2
Q=75.*CAU+20.*SQRT(CAU)+5000.
UCLCA=8.20
UCEC=0.0000013*XQ
UCECA=2.3+0.0011*CAU
UCMCA=0.0000005*XQ
UCMCA=0.003*CAUX*((AIRPR+14.7)/14.7+0.0025)*X0.242-1.)
CLAC=UCLCA*X24./AR*X1.12
CEAC=(UCEC+UCECA)*X24./AR*X0.715
CMAC=(UCHC+UCHCA)*X24./AR
GO TO 500
400 CLAC=0.
CEAC=0.
CMAC=0.
C -----
500 RETURN
END

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(Continued)

COSTUN Listing (Concluded)

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SUBROUTINE NEXSET(LO,LI)
  DIMENSION A(4),B(4)
  DATA A/4HEND,4HOF S,4HYTE,4HM
  WRITE(LO,1) A
  5 READ(LI,2) B
  DO 10 I=1,4
  IF(A(I).NE.B(I)) GO TO 5
10 CONTINUE
  RETURN
  1 FORMAT(1H1,4A4)
  2 FORMAT(4A4)
  END
SUBROUTINE ROCK(CLTS,CETS,CMTS,RQD,MEX,ISHAPE,BE,AR,RS,BE40,BE60,
11TYPE,Y,NSTYP,BF,ISUPPT,TPLATE,TSEG,PSOIL,WEB,PTCTAL,BOB,LINUT,
2NSTAB,CFLCA,HOURS,CFLWUK,CFEWUK,SFA,LINING,DM,CLL,CEL,CML,
3CLFU,CEFU,CMFU)
1010 SFP=3.14
  YY=0.0
  S=4.0
  V3=1.0
  UCL=Y3*(50+.04*BE**2)
  UCE=Y3*(5.5+.003*(BE+10.))*2)
  UCM=Y3*(2.1+.001*BE**2)*HOURS/AR+YY
1260 SEGN=3.
1270 CJOINT=BE*SFP/S+SEGN
  UCL=UCL+.175*CJOINT*AR/HOURS
  UCE=UCE+.025*CJOINT*AR/HOURS
  UCM=UCM+.3*CJOINT
  UBACKG=SFA*(BE**2-(BE-.333)**2)
  UCL=UCL+1.3*UBACKG*AR/HOURS
  UCE=UCE+.5*UBACKG*AR/HOURS
  UCM=UCM+1.2*UBACKG
  CLTS=(HOURS*CFLWUK+Y*DM)*UCL/AR
  CETS=HOURS*CFEWUK*UCE/AR
  CMTS=UCM
  CLL=0.0
  CEL=0.0
  CML=0.0
  CLFU=0.0
  CEFU=0.0
  CMFU=0.0
  RETURN
  END

```

```

087750 0000
087760 0000
087770 0000
087780 0000
087790 0000
087800 0000
087810 0000
087820 0000
087830 0000
087840 0000
087850 0000
087860 0000

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(Concluded)

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Bennett, Robert D.

Tunnel cost-estimating methods / by Robert D. Bennett (Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.

238 p. in various pagings : ill. ; 27 cm. -- (Technical report / U.S. Army Engineer Waterways Experiment Station ; GL-81-10)

Cover title.

"October 1981."

Final report.

"Prepared for Office, Chief of Engineers, U.S. Army under Project 4A762719AT40, Work Unit EO/005."

References: p. 50-52.

1. Cost. 2. Cost effectiveness. 3. Tunnels.

I. United States. Army. Corps of Engineers. Office of the Chief of Engineers. II. U.S. Army Engineer Waterways Experiment Station. Geotechnical Laboratory. III. Title IV. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; GL-81-10.

TA7.W34m no.GL-81-10

